2018

Assessing the Jurassic Cleveland-Lloyd bone bed predator trap hypothesis by statistical comparison of Allosaurus fragilis and Pleistocene La Brea Canis dirus femora

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Recommended Citation
Reddick, Angela D., "Assessing the Jurassic Cleveland-Lloyd bone bed predator trap hypothesis by statistical comparison of Allosaurus fragilis and Pleistocene La Brea Canis dirus femora" (2018). *Graduate Research Theses & Dissertations*. 1543.
https://huskiecommons.lib.niu.edu/allgraduate-thesesdissertations/1543

ABSTRACT

ASSESSING THE JURASSIC CLEVELAND-LLOYD BONE BED PREDATOR TRAP HYPOTHESIS BY STATISTICAL COMPARISON OF *ALLOSAURUS FRAGILIS* AND PLEISTOCENE LA BREA *CANIS DIRUS* FEMORA

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Since its discovery in 1939, the Late-Jurassic Cleveland-Lloyd Dinosaur Quarry (CLDQ) has been assumed to be a Jurassic predator trap by most visitors to the site. This idea's longevity is due in part to the disproportionately high ratio of carnivores to herbivores (3:1) uncovered from the quarry. However, despite decades of active research on the taphonomy and geochemistry of the deposit, the predator trap hypothesis remains unproven. In order to test whether the quarry does or does not have the characteristics of a predator trap, this study specifically analyzed the population of the quarry's most abundant animal, *Allosaurus fragilis*. The widely accepted predator trap that is the La Brea Tar Pits (LBTP) of Los Angeles, California, was used for comparison. For the most accurate analysis, femora belonging to *Allosaurus fragilis* from the CLDQ were compared to femora of *Canis dirus* from the LBTP by their femoral lengths and ratios. Every available bone from each animal was measured to produce as precise an analysis as possible. After all of these values were compiled, they were statistically compared using the Kolmogorov-Smirnov test. Results suggest that the two quarries do not exhibit the same population distribution. However, the same population at LBTP when divided into individual pits exhibited the same population distribution as the CLDQ. Hence, a Simpson's paradox has been achieved, which is when one trend is observed in separate groups of data but the trend reverses when the data is combined, which means that there is some additional

variable that has not yet been considered that is swaying the data. This leads to the conclusion that the quarry is not a predator trap, though in order to resolve the paradox, future studies and additional measurements are needed to complete a more thorough analysis.

NORTHERN ILLINOIS UNIVERSITY
DE KALB, ILLINOIS

AUGUST 2018

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BY

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE

MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY AND ENVIRONMENTMENTAL GEOSCIENCES

Thesis Director:
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ACKNOWLEDGEMENTS

Thank you to my advisors, Dr. Reed Scherer and Dr. Karen Samonds, for all of their suggestions and advice throughout this whole process.

Thank you to Dr. Joseph Peterson for suggesting this project for my research when I needed to start over and all of the subsequent advice and edits that followed.

Thank you to Carolyn Levitt-Bussian of the Natural History Museum of Utah for allowing me access to all the Allosaur femora within their collections.

Thank you to Aisling Farrell and Gary Takeuchi of the George C. Page Museum for granting me access to over 1,000 dire wolf femora.

Thank you to Peter Bishop from the Ancient Environments Program at the Queensland Museum in Queensland, Australia, for providing additional measurements of bones not available during my visit to Salt Lake City.

Thank you to Bill Wahl and Judy Massare for their assistance with editing and letting me know when my math was completely wrong.

Thank you, also, to Eric Evenson for helping me with travel and recording over 6,000 measurements and notes within two weeks time.

Thank you to the NIU Graduate School and Department of Geology and Environmental Geosciences for funding for travel expenses.

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INTRODUCTION

While the fossil record is fragmentary at best, in some rare cases it can give a very thorough glimpse of an unusual situation not normally observed. What is found preserved in rock either thousands or millions of years old is only a small subset of the original population, making comparison to modern environments difficult. However, based on the types of plants and animals found and their distributions, many inferences can still be made. For example, a catastrophic event generally kills all but the hardiest (or luckiest) of organisms, preserving a very specific type of assemblage. Contrarily, an attritional accumulation could show a bone bed biased towards a particular type of animal or a specific age group of animals. When this information is also considered with the geology of the area, very specific scenarios can be inferred or dismissed. Such as in the event of a supposed predator trap, where there is carcass domination or an overabundance of large social carnivores, it often leads to the assumption of a predator trap without too many questions to the contrary (Carbone et al. 2009). Two of the most recognized and often referenced cases of a predator trap include the La Brea Tar Pits (LBTP) for mammals and the Cleveland-Lloyd Dinosaur Quarry (CLDQ) for Jurassic dinosaurs.

Both sites have been studied extensively, but where the LBTP has been the poster child for a typical predator trap, the CLDQ deposit is not so easily defined. The CLDQ has long been subject to speculation ever since it was first excavated nearly 100 years ago by F. F. Hintze. In that time, at least nine taphonomic studies have been conducted (Dodson et al. 1980, Stokes 1985, Hunt 1986, Bilbey 1992, Richmond and Morris 1996, Bilbey 1999, Gates 2005, Hunt et al.

2006, Peterson et al. 2017) and tens of thousands of bones extracted by dozens of different groups. With an overabundance of the large carnivore *Allosaurus fragilis* and a relatively low number of herbivores, a predator-to-prey ratio of roughly 3 to 1 is apparent. Based almost solely on this fact, the quarry has been considered to be a predator trap for most of its known history; however, this is not universally accepted.

Ever since the first fossils were found in the Morrison Formation in 1877, it has been known as one of the most abundant dinosaur-producing formations in the world. Between 150.3 to 148.1 million years old (Kowallis et al. 1998), the Brushy Basin member, which contains the CLDQ, was uniquely situated to preserve a nearly perfect snapshot of the earth during a very prosperous time in its history. That being said, the geology of the area is unusual and has no modern analogue with which it can be easily compared. Its environments include everything from shallow marine in the Windy Hill member, to desert and marsh in the Brushy Basin member, to mud flats in the Tidwell member (Rees et al. 2004). Interpretations of the climate in the Brushy Basin member also vary wildly from desert to dry savannah to marshy wetlands (Rees et al. 2004). This has made it difficult to pin down exactly what may have trapped the animals there in the first place.

The original idea of the quarry being a predator trap has been questioned sporadically in the past; however, there have been very few studies designed to specifically refute or support this idea. Most are just concerned about the taphonomy of the quarry and look mainly at the geology and chemistry without observing the bones as more than a chemical time capsule. Due to this, many still follow the original predator trap model, though with different possible mechanisms driving the system.

This study is just the opposite; it was not designed to propose a new mechanism for why all the bones are there. It was designed to look specifically at the animals present to test if they really fit the predator-trap mold. For comparison, the LBTP, the most extensively studied and catalogued predator trap in the United States, was used as a control group. Instead of looking at the overall population by counts of species, the most populous species at each site (*Allosaurus fragilis* and *Canus dirus*) were compared by looking at their size distributions in their respective quarries. As most animals in each quarry consist of incomplete individuals that cannot be measured by anything more than isolated bones, a standardized comparison has to be mathematically calculated based on femur measurements. These bones were chosen as there are only two per animal and they can be easily correlated to an animal's size. By carefully measuring the femur length and circumference of all *Allosaurus* femora available for study from the CLDQ, the data can be compared to the *Canis dirus* femora found at the La Brea Tar Pits (LBTP) of Los Angeles, California. These values were all standardized before a Kolmogorov-Smirnov test was conducted to compare the distributions.

WHY LA BREA

As the control group, a brief overview of the La Brea Tar Pits follows.

History

In 1875 the first record of fossil bones discovered at Rancho La Brea was recorded by George Allan Hancock, but it was not until 1901 when W.W. Orcutt and F.M. Anderson began excavations of a site with more bones than matrix that the true significance of the site was recognized (Seaman 1914). Six years later, Professor Merriam of the University of California began excavation, which was followed by excavations conducted by the Southern California Academy of Science and then the Los Angeles High School (Seaman 1914). It was during this time that over 100 different sites were uncovered, and regular excavations have been occurring up to the present (Friscia 2008).

Geology and Stratigraphy

Most of the Rancho La Brea deposit is made up of sand and clay that has been soaked in asphalt that has migrated up through the underlying layers from an older Paleogene oil deposit to pool at the surface. It is generally thought that animals and plant remains were trapped before being covered by alluvial sediments from the Santa Monica Mountains (Quinn 1992).

The fossiliferous sediments are part of the Palos Verdes Sand that were formed during the late Pleistocene and in areas can exceed 150ft in thickness, which can be divided into three distinct members that have no formal names (Woodard and Marcus 1971). The lowest member is made up of mostly marine deposits including grey, brown, and black asphaltic siltstone and silty claystone. There are a few lenses of sand and gravel interbedded with the silt, and some fossil sponge spicules, radiolarians, foraminiferans, and gastropods are also present (Woodard and Marcus 1973). The middle is a 45ft layer comprised of a porous loosely consolidated, medium to fine-grained, angular quartz sand, highly intermixed with asphalt. The uppermost layer is comprised of three separate submembers mainly including clay, sand, and asphalt with a great variety of colors, textures, and thicknesses and contains most of the terrestrial fossil vertebrates (Woodard and Marcus 1973).

Fossil Accumulation

The bones preserved within the La BreaTar Pits have been so soaked with oil that most have been dyed a dark brown color but still retain the original bone material even after thousands of years underground (Seaman 1914). The most accepted mode of fossil accumulation at the tar pits is by entrapment in shallow pools of very sticky asphalt (Shaw and Quinn 1986, Stock and Harris 1992). The trapped animals, likely attracted carnivores as they were dying and unable to escape. Oddly enough, every skeleton is almost always disarticulated (Friscia et al. 2008). This is thought to be at least partially caused by movement within the pits from fluvial action and trampling (Shaw and Quinn 1986). However, there are some pits that show little to no weathering, indicating that the bones were buried rapidly, while some pieces from incomplete skeletons were thought to have been carried off by scavengers (Spencer et al. 2003). There is also some evidence of “pit wear” on the bones, presumed to be caused by the fluid-like behavior of each pool as well as the movement of gas bubbles up to the surface and the presumed constant upwelling of new tar into the pit (Woodard and Marcus 1973).

Each bone bed has a roughly round shape at the top that tapers down to a narrow channel at the bottom, formed mostly during the Late Pleistocene Epoch. It is thought that the surface pools of asphalt were most likely camouflaged by either transported sediment or water, making them difficult to spot by unwary animals (Merriam 1911, Stock 1929). Any animal that became trapped would attract predators that would then become trapped themselves, logically explaining the relative overabundance of predators in the area.

THE CLEVELAND-LLOYD DINOSAUR QUARRY

The following sections include an in-depth look at the test area, the Cleveland-Lloyd Dinosaur Quarry.

History

Although the first recorded excavations in the Cleveland-Lloyd area began in 1927 by F. F. Hintze and Golden York from the Department of Geology at the University of Utah in Salt Lake City (Madsen 1976), digging continued in 1929 under the direction of Dr. Frederick J. Pack (Miller et al. 1996). However, there is no record of continued digging until 1939 when William Lee Stokes led a group from Princeton University to visit the site to collect several hundred dinosaur bones up to 1941 (Bilbey 1999). Since then work has been continued sporadically by the University of Utah, the Utah Division of State History, and Brigham Young University (Miller et al. 1996, Bilbey 1999). Most recently the quarry has been worked by a collaboration of Dr. Joseph Peterson of the University of Wisconsin—Oshkosh, Dr. Jonathan Warnock of Indiana University in Pennsylvania, and students from Northern Illinois University and the University of Wisconsin—Oshkosh.

It was not until 1968 that the United States Bureau of Land Management was able to get the site declared a United States Natural Landmark and took over administration and protection of the quarry (Bilbey 1999). It is an unusual site in that most of the bones belong to many specimens of a single species of carnivore that are largely disarticulated and scattered throughout a layer that is only one meter thick (Hunt et al. 2006). There have also been more taphonomic studies of this quarry than any other in the Morrison Formation, including those by Dodson et al. (1980), Stokes (1985), Hunt (1986), Richmond and Morris (1996), Bilbey (1999), Gates (2005), and Hunt et al. (2006), none of which seem to completely agree on what specific circumstances led to the deposition and preservation of an extremely unusual bone bed.

Of the two most notable Morrison quarries in Utah, Dinosaur National Monument depicts a great deposit of nearly complete sauropods, whereas the Cleveland-Lloyd Quarry is its almost exact opposite, with greatly disarticulated theropod remains. Both quarries have yielded a wide variety of specimens, and as such, they are relatively well-known tourist attractions, both with bones left in situ for public observation. The two part-name of the Cleveland-Lloyd quarry comes from the neighboring town of Cleveland, Utah, and from a Pennsylvania lawyer, Malcom Lloyd Jr., who funded much of Princeton University's earliest work there (Stokes 1985). Overall the quarry has produced more than 10,000 dinosaur bones from at least 10 genera and more than 70 separate animals since its initial excavation in 1927 (Gates 2005).

Location

Located in central Utah, nestled in the heart of "Dinosaur Country" is the Cleveland-Lloyd Dinosaur Quarry. It is situated in Emery County about 13 km east of the town of Cleveland (Figure 1). It is found at the northern end of the San Rafael Swell (Hunt et al. 2006). An area of only $21m^2$ has been quarried, producing thousands of bones that have been collected during nearly 100 years of activity (Gates 2005).

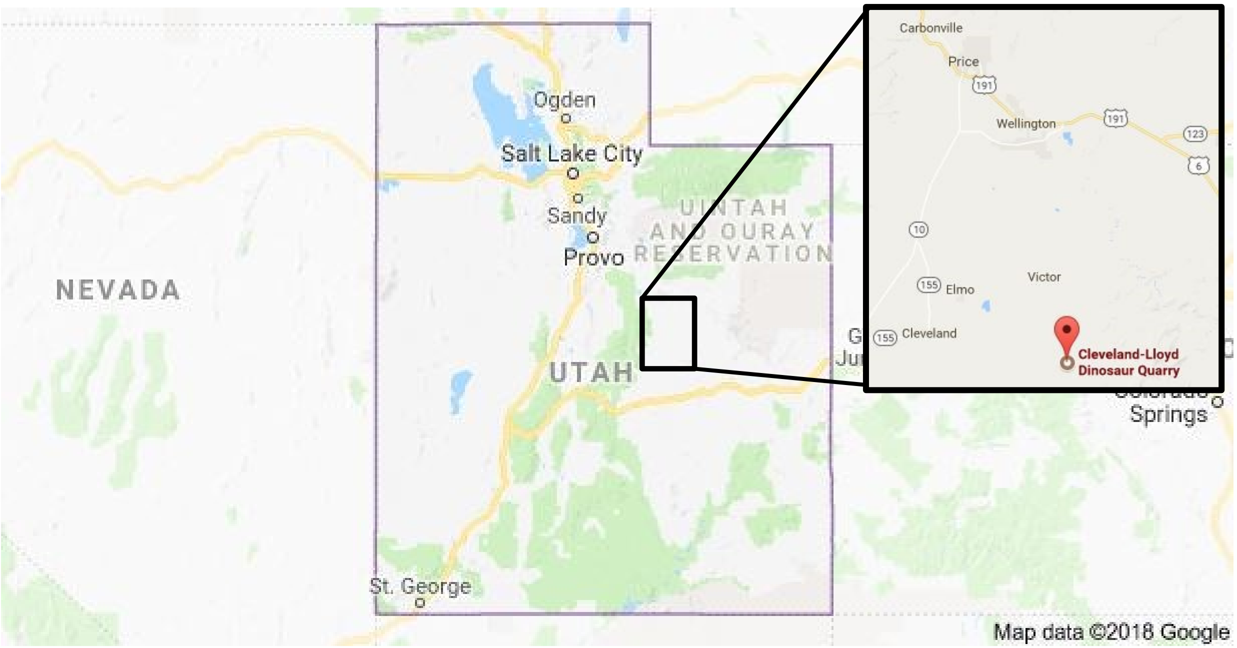


Figure 1: Map of the Cleveland-Lloyd Dinosaur Quarry. This figure shows the CLDQ relative to the surrounding towns and highways.

Geology and Stratigraphy

The entire Morrison Formation in, which the Cleveland-Lloyd Dinosaur Quarry resides, covers an area of roughly 1.5 million km^2 throughout the western interior of the United States and is a diverse continental deposit made up of limestone, sandstone, and claystone (Peterson et al. 1972). In this area of central Utah, the Morrison rests uncomfortably on the Summerville Formation of the Middle Jurassic (lower Oxfordian) and is overlain, disconformably, by the Lower Cretaceous (Aptian) Cedar Mountain Formation (Bilbey 1999).

The Morrison has been studied extensively for over a century by many different scientists (Gilluly and Reeside 1928, Gregory 1938, Peterson and Turner-Peterson 1987), and it has been subdivided into eight distinct members, of which the Tidwell member, Salt Wash member, and Brushy Basin member are the most extensive and make up the majority of the Morrison in the area surrounding the excavation site (Gates 2005). The quarry itself is located within the Brushy Basin member. All the members previously mentioned are accepted to be terrestrially derived, varying between semi-arid to river and floodplain environments. Within the quarry area the Brushy Basin member covers the greatest range but has not been correlated with a specific river or system (Stokes 1985).

Though the quarry only has a limited exposure, it appears that the unit it is part of thins laterally until it pinches out 50 to 75 meters south of the dig sites. This suggests the presence of a confined basin, though lacking the distinct pit shape that the LBTP exhibits (Gates 2005). Within this basin it has been found that the strata of the area dip between 2° to 7° in a north to north-west direction (Bilbey 1999). This indicates no or only slight alteration of the layer after deposition occurred. All the bones found within the quarry are buried in a calcareous mudstone that has been disturbed, most likely by the movement of other animals through the area, and directly below a micritic limestone of lacustrine origin known as the Cleveland-Lloyd lentil (Bilbey 1999). It has been found that the streams and rivers of the Brushy Basin Member carried far less sand and much more volcanic ash than the Salt Wash member. There are a few lenses of freshwater limestone deposited in shallow, temporary lakes like the limestone found overlying the quarry's bone bed (Stokes 1985).

The bone-bearing layer is made up of a calcareous smectitic claystone that has been severely disrupted, with calcareous nodules and many scattered and flattened intraclasts (Bilbey 1999). The smectite itself is made up of matrix and intraclasts with calcite as the main component of the matrix in the concretion, but only a minor part of the claystone. The calcite components are considered to be authigenic in the concretion and bioclastic in the claystone (Bilbey 1999), whereas, the limestone layer above the bone-bearing unit varies between 1 meter to 10 centimeters thick and has a very homogeneous mixture comprised of 52-56% calcite, 16-21% quartz, 13-23% clay, and 9-17% feldspar. This feldspar level is comparable to the percentages of the associated volcaniclastic beds. The clay component is mainly smectite with a small percentage of kaolinite. By this examination Bilbey (1999) classified the layer as a slightly fossiliferous, muddy micrite. It should also be noted that there is almost no apparent visual bedding within the layer and a few intraformational clay clasts (Gates 2005, Bilbey 1992). Aside from the bones, there have also been a few gastropods, charophytes, ostracodes, and carbonized plant material found at the site (Gates 2005).

Cleveland-Lloyd Dinosaur Quarry Age

In order to get an accurate age range for the quarry, a smectitic claystone lying 0.5 to 1.0 meters above the quarry's limestone cap, which is all that remains of a graded volcanic tuff, was sampled. Using two biotite samples from this layer, K-Ar analysis yielded lower age estimates of 146±1Ma with 10.4% atmospheric argon and 147.2±1Ma with 12.1% atmospheric argon. Similarly, another biotite-rich claystone found 3 meters below the quarry layer was dated at about 152 Ma using the same method (Bilbey 1999). This gives an average age for the deposit of about 149Ma within the Tithonian/Portlandian stage of the Late Jurassic (Gates 2005).

Depositional Settings

While all researchers studying the Cleveland-Lloyd Dinosaur Quarry examine the same rocks and minerals, their interpretations of the depositional environment have varied greatly over the years. As previously mentioned, it is settled well within the Late-Jurassic Brushy Basin member of the Morrison Formation. Based on a study done by Dodson et al. (1980), four distinct facies have been recognized within the Morrison, including fluvial deposits with clastics present, soil deposits of variegated mudstones, a second “drab” mudstone deposit thought to be a reducing environment, and a lacustrine deposit made up of limestone marl. Within the state of Utah, the Jurassic Period was characterized by three distinct paleoenvironments: a sandy desert, a series of alternating advances and retreats of a shallow marine environment, and a large expanse of river systems and shifting freshwater lakes (Stokes 1985).

The most extensive unit of the Morrison Formation is the Brushy Basin member, within which the quarry is situated. It is estimated to have at one time covered as much as 750,000 square miles across the Western United States (Stokes 1985). There is very little sand present in this member, though the deposit is considered to have the same origin as the Salt Wash member below it (Peterson and Turner-Peterson 1987). The main components of this member are variegated mudstone, drab-gray mudstone, and limestone marl. These are interpreted to be from a well-drained floodplain, a poorly drained floodplain, and a freshwater lake respectively (Dodson et al. 1980). There are also interbedded layers of bentonite from a magmatic arc to the west of the quarry (Dodson et al. 1980, Peterson and Turner-Peterson 1987, Bilbey 1992). Overall the depositional environment is thought to be dominated by a meandering river-system floodplain with associated lakes (Dodson et al. 1980, Gates 2005).

Demko and Parrish (1998) even created climatic reconstructions of Utah's Morrison Formation depicting a seasonally arid environment with significantly less rainfall than the surrounding area. Geologic evidence seems to support this by the very rare presence of coal deposits and plant remains (Dodson et al. 1980) and the possible presence of authigenic clay minerals in distinct basin-wide, bulls-eye patterns that are only known to occur in arid environments (Turner and Fishman 1991). From an interpretive standpoint, there are very few modern locations demonstrating semi-arid environments with widespread river systems depositing sediments deep within a continent, making it very difficult to compare and fully understand the Morrison Formation today (Stokes 1985). This explains why there are still many different interpretations of even a single dig site within the formation.

Although it is widely accepted that the Cleveland-Lloyd Dinosaur Quarry was deposited in a lacustrine environment, there have been many varying interpretations on the origin for this lake. Dodson et al. (1980) interpreted it as an oxbow lake, while Richmond and Morris (1996) considered it to be a pond in the floodplain of an anastomosing river system. It has been found that within the Cleveland-Lloyd Dinosaur Quarry both large and small bones and bone pieces are preserved, giving the indication of little to no current moving through the area during the time of deposition, leading evidence to support a floodplain deposit (Stokes 1985). But just having a floodplain does not explain why so many different animals and a concentration of large predators would have died and been preserved here. In an attempt to explain this, Bilbey (1999) proposed that the dinosaur bones were deposited and preserved in a spring-fed pond or seep, based on a petrologic analysis of four cores through the fossil-bearing layer. She also found evidence for intermittent flooding of the area (consistent with Stoke's earlier assessment), but with major reworking of the bones by other animals and/or flow of the spring.

In Bilbey's study (1999), she found that while the initial geology is that of a shallow lake with an underground source, it was previously thought that all the bones were preserved in volcanic ash-rich mud, based on the existence of a single dinosaur egg, many calcareous mudstone nodules, and mostly disarticulated skeletons. As there is very little evidence of scavenging, the bones are thought to have been buried before other animals could gain access to the remains. While some of the bones may have skeletonized before burial, the presence of barium nodules associated with some bones indicates that at least some flesh was present at the time of burial. However, it is thought that movement of other animals trapped in the mud and possible circulation of up-welling water disarticulated the bones to the degree they are found today, which is similar to what occurred at the LBTP (Bilbey 1999).

Similar to Bilbey's interpretation, Gates (2005) thought the quarry was deposited by an ephemeral pond. Both spring-fed and ephemeral hypotheses are reasonably supported by the previously mentioned evidence, though there is no specific criteria presented by Bilbey to support her hypothesis of a spring-fed seep, according to Hunt et al. (2006). The idea of an ephemeral pond has sense gained more support by a recent study conducted by Peterson et al. (2017) where XRD and XRF analyses showed a high concentration of heavy metals which could potentially be due to the decaying flesh of the dinosaurs present at the quarry or at least partly due to diagenetic alterations within the quarry.

Often overlooked within the quarry deposit, there is a distinct lack of invertebrate fauna, as well as a lack of fish and amphibian fossils, indicating that the waterbody may have seasonally or cyclically run dry. There have been very few crocodile teeth and a few pieces of turtle shell found at the site, which supports the idea of dramatic seasonal changes as well since aquatic animals could not live in an environment that does not support a constant water source. This would be consistent with an ephemeral pond environment (Gates 2005). More evidence in support of this hypothesis includes indications of desiccation, including intraformational clay rip-up clasts representing movement and redeposition of mud-cracked sediments (Gates 2005). This makes sense with alternating dry periods and possible seasonal flooding (Gates 2005, Peterson et al. 2017). When considering the nodules found in close proximity to the bones, it is thought that they formed around the bones as a result of a calcic soap being formed by bacteria as organic material decayed (Berner 1968, Bilbey 1992). This explains the initial precipitation of calcite, but the remaining nodule most likely was sourced from either ground water or from dissolved volcanic ash, which is abundant in the deposit (Gates 2005). The fact this water may have also been hypereutrophic would restrict or completely eliminate the chance of finding microverterbrate remains or scavenging and is also supported by the high abundance of sulfides within the layer (Peterson et al. 2017).

The mudstone of the quarry is covered by a dense limestone layer that marks the end of the ephemeral pond as well as the last deposits of large bones and the transition to a permanently flooded environment (Gates 2005). There is also a distinct undulating contact between these two layers. There have been two proposed reasons for this type of contact; the first proposed by Richmond and Morris (1996) is that it is due to a rapid formation of limestone over watersaturated mud. The second idea from Gates (2005) is in support of bioturbation, where many large dinosaurs moved through the area warping any former bedding and creating an indistinct and rippled contact between the layers. This would make sense; as there are so many bones in the area, it would be reasonable to conclude that there were many live animals moving through the area as well.

PAST HYPOTHESES

Scientists have proposed many different ideas on the origin of the Cleveland-Lloyd Dinosaur Quarry. One of the first hypotheses was proposed by Stokes (1945), who considered the bones to have been deposited in a calcareous mudstone, most likely forming when the animals died in an evaporating pond or lake. Over 30 years later, Madsen (1976) proposed that the quarry bones may have been disarticulated before burial, meaning that there was a time of surface exposure. Four years later, Dodson et al. (1980) concluded that the quarry was a predator trap, specifically formed in a bog created by an oxbow lake.

After 40 years of no written comment, Stokes altered his hypothesis. In his 1985 paper, he stated that as the bones are not distributed in distinct layers, and they do not have a wide distribution with little surface exposure, he concluded that the bones sank into the water-logged sediment rather than being deposited on top of the layer. This hypothesis does agree with the idea of a bog, where the animals would have accumulated over a substantial amount of time, and the disarticulation occurred by internal movement of the bog as it settled, though it lacks the typical plant fossils found in most bog environments (Stokes 1985). One year later, Hunt (1986) made yet another suggestion with two possibilities: miring and catastrophic flooding (1986). The abundance of carnivore bones and the existence of even the most delicate elements do suggest miring. However, due to the presence of intraformational rip-up clasts, the planar geometry of the layer and the nearly horizontal orientation of the bones within the unit, a catastrophic origin makes sense as well (Hunt 1986).

Another hypothesis proposed by Richmond and Morris (1996), 10 years after Hunt is that the mudstone accumulated in the floodplain area off of an anastomosing fluvial system (1996). They propose that the dinosaurs were entrapped while drinking and hunting around the floodplain, and the expansive properties of smectitic clays like those in the quarry would account for all the disarticulation and lack of orientation within the bed (Richmond and Morris 1996).

According to Bilbey (1999), the quarry was an obvious predator trap based on the presence of only a few herbivorous dinosaurs and an abundance of *Allosaurus*. She thought that the animals that died there were mired in a spring-fed pond or seep and Richmond and Morris (1996) estimated that the depth was around 7 meters. Then they were scattered by "dinoturbation," that is the movement of other living animals struggling in the mud and changes in the ground water level (Lander and Hay 1993). The upwelling water allowed the larger bones to settle to the bottom of the mud with the smaller bones suspended above. Later ash falls filled the lake and helped preserve the bones in a calcareous mud (Bilbey 1999).

Hunt et al. (2006) concluded that there must have been some lateral movement within the pond. Evidence supporting this includes sandstone stringers, extraformational sandstone grains and mudstone rip-up clasts, as well as a fining upward sequence of bones, a rough orientation to the bones and some minor fracturing (Hunt et al. 2006). Transport must have been brief and still rather slow, but with the relatively small size of the Allosaurs, vertebrae and ribs exhibit the most abrasion and there is a lack of chevrons, phalanges, metapodials and tarsals/carpals (Hunt et al. 2006). This would lead to the hypothesis that the smaller bones could have been washed away, then a sheet flood moved the remaining bones into a topographic low where they were preserved for scientists to find over the past 100 years (Hunt et al. 2006).

In summary, Stokes (1945) concluded that the dinosaurs at Cleveland-Lloyd died in an evaporating pond and were disarticulated by trampling and scavenging. Dodson et al. (1980) considered the site to be a predator trap where the animals were mired in a bog formed in an oxbow lake. Bilbey (1992, 1998, 1999) consistently agreed that the site was a predator trap where the animals were stuck in a spring-fed pond and the bones became scattered as water up-welled to the surface and living animals struggled in the mud. Stoke's (1985) altered hypothesis concluded it was a predator trap in a bog where the bones were sunk over time and internal movement in the bog dispersed the skeletons (1985). Hunt (1986, Hunt et al. 2006) gave evidence for both attritional (predator trap) and catastrophic sequences, with the bones scattered in a low-energy environment. Richmond and Morris (1996) considered the site to be a flood pond and the disproportionate number of Allosaurs was based on the idea that they hunted in packs and that bipedal animals would have a harder time pulling themselves out of the mud than quadrupedal animals. Gates (2005) was one of the first to propose an idea not in agreement with the predator trap model, believing the site to be a drought-induced death assemblage around a longer lasting source of water. The large number of carnivores in the area would have intimidated most of the herbivores enough that they most likely would have stayed clear of the area (Gates 2005).

Species Present

Within the Morrison Formation, eleven different theropod genera have been identified (Foster and Chure 2006). Of those eleven, *Allosaurus* is among the most common. Over 150 identified specimens of *Allosaurus* have been found from 100 different localities throughout the western United States (Foster and Chure 2006). And throughout varying depositional environments and stratigraphic levels, it represents nearly 70% of all identified theropod specimens (Foster and Chure 2006). It should be noted, though, that the abundance of *Allosaurus* fossils in the Morrison are greatly inflated because of the bones found at Cleveland-Lloyd. From this single quarry, nearly half of the known theropod genera of the Morrison have been identified—*Allosaurus*, *Stokesosaurus*, *Marsjosaurus*, *Ceratosaurus*, *Torvosaurus*, and *Tanycolagreus* (Foster and Chure 2006).

There are a minimum of seventy-three individual dinosaurs within the quarry as well as one crocodilyliform and two possible *Glytops* turtles (Hunt et al. 2006). Of the 73 dinosaur specimens, 53 are theropods, and of the theropods, 46 have been identified as *Allosaurus fragilis* (Hunt et al. 2006). Aside from dinosaurs, the quarry has also produced four species of gastropods, three species of charophytes and ostracods, and one species of chelonian (Miller et al. 1996). Specifically represented within the Cleveland-Lloyd Dinosaur Quarry are the following theropods: *Allosaurus fragilis* (46), *Stokesosaurus clevelandi* (2), *Marshosaurus bicentesimus* (2), *Ceratosaruus dentisulcatus* (1), and *Torvosaurus ef. Taneri* (1); the sauropods *Camarasaurus lentus* (5), *Barosaurus sp?*(1), and *Apatosaurus* (1) (Foster and Chure 2006; Foster and Peterson 2016); the thyreophora *Stegosaurus cf. stenops* (5); and the ornithopoda *Camptosaurus* (5). It is possible that there are other species of plant, pollen, and spores present at the site; however, they are very unlikely to be found due to the site being hypereutrophic (Peterson et al. 2017).

Based on a count of left femora, there are at least 46 individuals of *Allosaurus* (Madsen 1976, Gates 2005). While the *Allosaurus* specimens range from juvenile to adult, most other species present appear to all be fully grown adults. This assumption is based on the large size of most of the recognizable elements and the presence of only fused vertebrae in the quarry, which have previously been considered indicators of adulthood (Gates 2005). Madsen also considered 56cm to be the division between subadult and adult Allosaurs, and based on this measurement, it has been found that nearly 82% of those specimens identified as *Allosaurus* are in the juvenile to subadult range (Gates 2005).

Bone Distribution and Orientation

As previously mentioned, there is a clear pattern to the distribution of bones within the quarry; the largest bones all lie approximately horizontal at the bottom of the deposit, with smaller bones and fragments scattered throughout the upper section of the bone-bearing layer and into the overlying limestone (Madsen 1976, Bilbey 1999). Very few bones can be conclusively identified as belonging to a single individual, as most are disarticulated and mixed with bones of other animals over more than 60m^2 (Madsen 1976, Bilbey 1999). Most of the bones are preserved in excellent condition, even with much of their original microstructure undamaged (Madsen 1976, Bilbey 1999). There are only a few bones with breaks in them and even fewer abraded or eroded sections (Madsen 1976, Bilbey 1999). There has been some evidence of scavenging of lower limb elements, indicating that those bones were exposed for some time before burial (Gates 2005). Most of the bones are estimated to have a subaerial exposure time of less than two years (Behrensmeyer 1978), after which rapid burial occurred (Gifford 1985, Gates 2005).

Based on Fiorillo's (1988) abrasion scale, 37% of the bones show a very low level of abrasion, and only 4% show signs of weathering (Gates 2005). Of the bones found, 30% are fractured and 34% are abraded but no bones have evident scratch marks, indicating a confusing list of evidence for and against trampling by other dinosaurs (Brain 1967, Haynes 1991, White 1992). There is also the chance that fracturing could have occurred from feeding carnivores, but the lack of tooth-marked bones (only 4% and only from herbivores) makes this unlikely (Hill 1989, Gates 2005).

Of all the bones found, those with a noticeable long axis are oriented horizontal to sup-horizontal but have no obvious preferred trend to indicate direction of flow (Hunt et al. 2006). However, Gates (2005) did notice a preferred orientation of smaller bones plotted from the 2001-2002 excavation, indicating there may have been minor currents in the area that could rework the smaller pieces but not the larger ones (Peterson et al. 2017). While there is very little articulation of bones in the quarry, there does appear to be association among a few sauropod vertebrae, some *Allosaurus* vertebrae, a partial pelvis, and two skulls (Gates 2005), as well as a slight clustering of tooth-bearing elements (Richmond and Morris 1996). There is also no consistent bone density per square meter, with a maximum of 60 bones/m^2 (Gates 2005).

JUSTIFICATION

The following information is summarized in Table 1 to display an easy-to-read direct comparison of both species. The last specimen of *Allosaurus fragilis* died off roughly 139.7 million years before the first dire wolf appeared (Madsen 1976, Stock and Harris 1992). During that time the western United States underwent many geologic changes transitioning from a warm, semi-arid environment to a much cooler and wetter place in which each aforementioned species could thrive respectively (Olsen et al. 2002, Coltrain et al. 2004). The massive expanses of grassless, savannah-like plains with sporadic lakes and rivers of the Late Jurassic were a perfect place for *A. fragilis* to dominate, whereas the grass-dominated smaller plains and forested mountains of the Late Pleistocene and Holocene were better suited for large carnivorous mammals such as *C. dirus* (Olsen 2002, Coltrain et al. 2004). However, despite their drastic age differences, both animals were among the top predators of the western United States during their respective ages.

When considering their sizes, the Allosaur outweighed the dire wolf by an estimated 1460-1930kg and an overall length of 7-10.5m (Anton and Turner 1997, Madsen 1976, Anyonge and Roman 2006, Bates et al. 2009). Both animals are presumed to have a determinate growth pattern but reached sexual and somatic maturity at very different ages, 16 and 20 years respectively for *A. fragilis* and both are reached around 2 years for *C. dirus* (Lee and Werning 2008, O'Keef et al. 2014). It is also estimated that Allosaurs could outlive wolves by nearly 20 years (Bybee et al. 2006).

Table 1

Biological and ecological comparison of *A. fragilis* and *C. dirus*

Categories	***Allosaurus fragilis***	***Canis dirus***
Comparative morphology		
Size	1,500-2,000kg (Bates et al. 2009)	34-67kg (Anyonge and Roman 2006)
Length	Average: 8.5m, Maximum: 12m (Madsen 1976)	1.5m (Anton and Turner 1997)
Height	3-5m (Madsen 1976)	At shoulder: 0.8m (Anton and Turner 1997)
Growth	Determinate	Determinate
Age of sexual maturity	~16 (Lee and Werning 2008)	~2 years
Age of somatic maturity	~20 (Lee and Werning 2008)	~2 years (O'Keef et al. 2014)
Average Femur length	~.584m	~.23m
Skull	Narrow and long (Madsen 1976)	Shows evidence for the attachment of very powerful jaw muscles (Anyonge and Baker 2006) (Anyonge et al 2003)
Teeth	Triangular shaped, serrated (Madsen 1976)	Large and strong, good for holding onto prey
Life span	~28 years (Bybee et al. 2005)	~6-8 years, Estimated to be similar to modern wolves
Prehistoric distribution		
Time period	Late Jurassic (150-140 mya) (Madsen 1976)	Late Pleistocene (300,000-12,000 years ago) (Stock and Harris 1992)
Expanse	North America (Madsen 1976) and Portugal (Pérez-Moreno et al. 1999)	North America and northern South America (Stock and Harris 1992)
Habitat	Savanna-like though without grasses (Olsen 2002)	Variable, open plains to forested mountains (Coltrain et al. 2004)
Climate	Warmer than today, semiarid, seasonally dry (Olsen 2002)	Cooler and wetter than in California today (Coltrain et al. 2004)

(Continued on next page)

Table 1 (continued)

Ecology and Behavior		
Sociality	Likely lived in family groups (Richmond and Morris 1996,*)	Likely lived in large groups or packs (Van Valkenburgh and Sacco 2002)
Dominace	The largest individuals likely dominated the group*	Males dominant over females
Hierarchy	Likely no easily defined hierarchy*	No easily defined linear hierarchy (Fox 1973)
Vocalizations	Used after hatching, to display dominance and find mates*	Used to establish territory and communicate with pack members (Lopez 1978)
Pack Structure		
Transitionary pack size	Unknown	Average between 2-4 (Sparkman et al. 2012)
Established pack size	2-5**	Between 5-20 (Stenglein et al. 2011)
Pack distribution ratio (adult:juvenile)	Unknown	Average 5:3 (Stenglein et al. 2011)
Age of juvenile dispersal	Around 2 years old*	Between 1 and 3 years old
Feeding habits and hunting styles		
Bite force	~600PSI (Rayfield et al. 2001)	~500PSI (Therrien 2005)
	4179-6809N (Bates and Falkingham 2012)	~1800N (Bates and Falkingham 2012)
Prey	Large sauropods, stegosaurs and iguanodonts	Horses, sloth, camel, possibly mastodon and bison as well. (Fox-Dobbs et al. 2007)
Sense of smell	Well developed (Rodgers 1998)	Well developed (Fox 1973)
Migration	Prey likely to migrate, but likely not typical of *A. fragilis* (Fricke et al. 2011)	Prey migrated, but not likely to follow unless other prey was scarce (Ballard et al. 1997)
Nesting/denning	Likely to have established nesting grounds (Lockley et al. 2016)	Used established dens to keep young safe (Ballard et al. 1997)

*Based on crocodilian relationship (Lang 1987).

**Based on King vultures behavior at a carcas (Wallace and Temple 1987)

Despite the dramatic size differences and uniquely specialized teeth, their bite forces were possibly rather similar: an estimated 600PSI for the Allosaur and 500PSI for the wolf (Rayfield et al. 2001, Therrien 2005). This may be explained by the differences in their teeth. *A. fragilis* had very sharp, serrated, triangular-shaped teeth that were best suited for cutting and slicing, while *C. dirus* had heterodont dentition with large cone-shaped teeth better suited to grasp and hold onto prey (Madsen 1976, Fox-Dobbs et al. 2007). Relative to the animal's size, the sharper teeth and homodont dentition possessed by the dinosaur would require a relatively smaller bite force to pierce flesh using instead rapid strikes to subdue prey (Snively and Russell 2007, Snively et al. 2013), whereas the blunter teeth of the wolf would require a larger bite force in order to puncture the skin of its prey. *A. fragilis* specialized in hunting dinosaurs far larger than itself, including sauropods, iguanodonts and the occasional stegosaur (Madsen 1976). While *C. dirus* also hunted animals larger than itself, it specialized in mammals such as horses, deer and elk, sloths, camels, and possibly mastodons and bison (Fox-Dobbs et al. 2007). Both were likely to rely heavily on their well-developed senses of smell to help find their prey (Rodgers 1998, Fox 1973). It is on the hunting methods and social behaviors that these animals developed that we will now focus on.

In order to properly examine the hunting and social behaviors of two extinct species, modern analogues must first be identified. For the case of *C. dirus*, that is relatively easy; they have a very close living relative in *Canus lupis*, the modern grey wolf. However, to get an overall picture of *A. fragilis* we must examine a few different living species. It has been found that Allosaurs have a ball-and-socket joint between their opisthocoelous vertebral centra, indicating that they had a highly mobile neck (Madsen 1976, Holtz et al. 2004, Brusatte and

Sereno 2007, Snively et al. 2013). This makes it very likely that Allosaurs were capable of making a rapid downward strike to incapacitate prey, an action most similar to the bald eagle and snowy owl (Samman 2006, Snively et al. 2013). Allosaurs were also able to exert a strong ventroflexive torque, implying that they exercised a rather birdlike posterior pull on a carcass (Snively et al. 2013). This also suggests that, like modern raptors, they would likely brace they body of a prey item using their feet, grasp some flesh with their sharp teeth, then pull up and back with strong neck muscles (Snively 2006, Snively et al. 2013). This makes raptors an excellent reference for feeding methods when considering both active hunting and scavenging habits.

It has also been shown that there are many similarities between birds and crocodiles, such as similar amino acid structure in β-keratin between the Nile crocodile (*Crocodylus niloticus*) scales and the scales of chicken's claws. Bagwill et al. (2009) completed a study on the American alligator (*Alligator mississippiensis*) noting seasonal changes in the oviduct with structural homologies that birds also share. The pattern of development in teeth of mutant chickens studied by Harris et al. (2006) shows a line of descent between dinosaurs and birds, and the tendency of crocodilians to shed and replace their teeth is similar to hypothesized tooth replacement in theropod dinosaurs (Brazaitis 1981, Erickson 1996). There have also been noted similarities in incremental lines of the dentine in dinosaur teeth and teeth of both living and prehistoric crocodilians (Erickson 1996). Additional evidence of this shared link includes the presence of gastroliths in many extant crocodilians (Cott 1961, Brazaitis 1969), birds, and dinosaurs (Wings 2007). This evidence implies that while birds are likely *A. fragilis's* closest living relative, Crocodilians are a good outlier from which to also infer feeding and social behaviors of the extinct group as they work as both an ecological and phylogenetic out-group.

It is commonly known that modern wolves are very social animals, living and hunting in packs made up of 2 to 20 individuals. There are many reasons as to why this lifestyle could be beneficial. A reasonable assumption would be that with larger groups hunting together, more food can be acquired per wolf, increasing their overall success (Nudds 1978). However, even when hunting the largest available prey such as bison or moose, a single pair of adult grey wolves can be just as successful as a larger group, with more meat available to each animal after the kill (Schmidt and Mech 1997). Studies by Thurber and Peterson (1993), Hayes (1995), and Dale et al. (1994) clearly refute the idea that wolves live in packs in order to hunt larger prey. Each study showed that regardless of what kind of prey the packs hunted, in every case the larger the number of wolves per pack, the less food was available per wolf.

While counterintuitive to begin with, when it is noticed that most wolf packs consist of a breeding pair of adults and their maturing pups, their motives begin to make more sense (Mech 1970, 1999). It has been observed that most offspring leave the pack by age 3 (Fritts and Mech 1981, Peterson et al. 1984, Ballard et al. 1987, Mech 1987, Fuller 1989, Gese and Mech 1991, Lehman et al. 1992, Meier et al. 1995, Smith et al. 1997). These observations lend credence to the idea that packs actually exist as a way for adults to share the excess meat they attain from a kill with their immediate offspring, instead of leaving it for scavengers, thus increasing their overall fitness (Schmidt and Mech 1997).

In comparison, Wallace and Temple (1987) conducted a study on thousands of avian scavengers at 214 different carcasses in northern Peru to determine social behaviors and dominance hierarchies. It was observed that king vultures often arrived at a carcass in pairs or family groups, much like wolves. They would even make a point of defending the carcass from smaller animals, which allowed their own young to feed more easily (Wallace and Temple 1987). Other observed birds such as the smaller black vultures and larger condors exhibited their own if less sophisticated hierarchy where the smaller and younger animals yielded readily to the larger and older ones (Wallace and Temple 1987). From this evidence it is reasonable to assume that Allosaurs could have at least existed in hierarchy-based groups during feeding time, if not always to ensure the survival and success of their own offspring.

Even crocodilians' observed behaviors support this idea. While most appear to be constantly solitary, groups can congregate at specific times of the year. For example, *A. mississippiensis* of coastal Louisiana will gather together in the spring in groups of up to 10 animals before dispersing once again after mating has occurred (Joanen and McNease 1980). Also, *Crocodylus niloticus* in Lake Rudolf will form substantially larger groups for mating, including more than 200 individuals dominated by fewer than 15 males that remain together throughout the entire breeding and hatching period before dispersing once again (Modha 1967, 1968).

Outside of the mating season, hatchlings of *A. mississippiensis* will periodically form groups for protection if they are not constantly under the care of their mother. *C. niloticus* mothers will defend their young against other predators and many crocodilians will carry their young in their mouths for protection until they are old enough to take care of themselves

(Garrick and Lang 1977). Juveniles and adults of *A. mississipiensis* and *C. niloticus* will also frequently gather in basking groups during the day that may be separated by size or age, where the animals become less agonistic towards one another and during these times they may even use co-operative hunting to take down larger than average prey (Pooley and Gans 1976, Schaller and Crawshaw 1982, Whitaker and Whitaker 1984, Lang 1987). It has been speculated that Allosaurs congregated in groups of 200; from this information it can be shown that even as adults, group behavior is exhibited even in the least social dinosaur relatives (Bakker and Bir 2004).

Wolves bark and howl, birds (and presidents) tweet and sing, crocodiles squeak and growl. Nearly every known animal expresses some type of vocalization. Modern grey wolves use these sounds to communicate with pack members over long distances, request attention from parents or other pack members, indicate pain or sadness, and fortify social bonds (Harrington and Mech 1979). They will also periodically scrape or dig at the ground to mark their territory. Birds also use their songs and calls for a myriad of different reasons. They can be used to attract mates, mark territory, and communicate with other birds. Calls can also be used to express emotion, and the tweets of hatchlings for their parents care is a sound birds are programed to respond to. Crocodilians even have different vocalizations they can utilize including bellowing, growling, “roaring,” hissing, and barking (Garrick and Lang 1977). These sounds are used when in distress, as a sign of aggression, or in order to attract mates (Garrick and Lang 1977). Even hatchlings will repeatedly vocalize to request maternal care and attention (Garrick and Lang 1977).

Unfortunately, it is impossible to find any physical evidence of extinct creature's vocalizing. Although we may be able to recreate what an animal sounded like, we can never with one hundred percent certainty say exactly why they were making those sounds. However, trace fossils found by Lockley and collegues (2016) indicate a similarity between birds that has only ever been speculated about before: courtship rituals. They found four sites containing deep grooves and scrapes within the Dakota Sandstone that are most consistent with nest scrape display activity seen in many modern birds (Lockley et al. 2016). While indirect, this is evidence supporting the idea that if some theropod dinosaurs participated in display rituals, they would likely also use vocalizations to enhance those displays. Thus, it can be presumed that *A. fragilis* vocalized for many of the same reasons as modern birds vocalize today. Sharing the tendency to use both scrapes and vocalizations to convey messages with the modern wolf, long-extinct Allosaurs can be thought to exhibit behaviors similar to the dire wolf.

It is commonly known that many large herbivores migrate, but what is rarely thought about is what the carnivores that prey on migrating animals do in response to migrations. Wolves in Alaska generally prey on large herds of caribou. However, when they migrate out of the wolves' resident territories, they will usually switch to preying on moose instead (Ballard et al. 1987). In the few years when there were not as many moose around, the wolf packs would instead follow the caribou, but would always return to their original territory to have their pups (Ballard et al. 1987).

It has been debated in the past whether or not large dinosaurs would migrate like modern animals. In a study by Fricke et al. (2011), the oxygen isotope ratios extracted from the tooth enamel of *Camarasaurus* were used to determine that these large herbivores did in fact migrate.

By comparing the ratios in the teeth to those found in ancient soils, they were able to show that at least some large sauropods would migrate from lowland to upland environments and back again. From their study they concluded that *Camarasaurus* migrated out of a basin setting in the dry season to a more upland area, then returned during the wet season (Fricke et al. 2011). It is likely then that *A. fragilis,* that frequently preyed on *Camarasaurus*, would maintain a home territory, hunting whatever remained while the *Camarasaurus* was absent. They also may have maintained specific nesting grounds in which to lay their eggs and raise their young, just as birds typically do.

While there are many differences between *C. dirus* and *A. fragilis*, the long list of similarities contained in Table 1 and previously discussed, makes it reasonable to conclude that both animals would have had similar reactions if placed in similar situations. The fact that both were likely to roam in family packs indicates that if they came upon a trapped animal while hunting, each group would have taken advantage of an easy meal. Then if they did become mired and unable to escape, the fossil record would display an equivalent proportion of those individuals for each location. Hence, the population distribution of *C. dirus* at Rancho La Brea, being typical of a predator trap, should match in proportion the distribution of *A. fragilis* at the CLDQ if it was a predator trap as well.

Finally, to complete the site comparisons, is a discussion of the deposition at each site. First, Rancho La Brea as previously mentioned is made up of asphalt-soaked sand and clay, whereas the CLDQ is almost entirely made up of dense calcareous mudstones (Bilbey 1992, Quinn 1992, Richmond and Morris 1996, Gates 2005, Peterson et al. 2017). This initial description makes the two sites appear more different than similar; however, both sites are perfect for getting animals stuck and keeping them that way. As evidenced by modern observations of animals currently getting stuck in the tar at LBTP, and from a study conducted by Richmond and Morris (1996), the original CLDQ mud layer was significantly thicker at deposition than it currently appears, which goes a long way for keeping struggling animals in place. It has also been found that the weight/area for even the smallest Allosaurus found at the CLDQ was significantly higher than that of an adult human, meaning they are even more likely to get stuck in this mud than other quadrupedal dinosaurs living at the same time (Richmond and Morris 1996). Thus, despite the previously mentioned differences in the deposition of the sites, they were both fully capable of keeping large predators contained within their sediments. This leads to the possible conclusion that both of these large predators lived in similar life situations and, when faced with similar "trapping" possibilities, the same size distribution of animals should be found in both locations.

HYPOTHESIS

Conducting a two-sample Kolmogorov-Smirnov test, we can test at a 95% confidence interval, if we can reject or fail to reject the null hypothesis that follows:

Null hypothesis: The population distribution of *Allosaurus fragilis* at the Cleveland-Lloyd Dinosaur Quarry is the same as the population distribution of *Canis dirus* at the La Brea Tar Pits.

Alternative hypothesis: The population distribution of *A. fragilis* significantly differs from the population distribution of *C. dirus* at their respective locations.

With a sample size of n=1043 at the tar pits, there is a substantial data set with which to compare the sample of bones from Cleveland-Lloyd (either n=34 or n=65).

METHODS

There are few methods to distinguish between attritional and catastrophic assemblages of fossil bone beds, the first of which was suggested by Voorhies (1969) using age distribution data (Hunt et al. 2006). This paper will use a similar technique by comparing the age distribution of the Cleveland-Lloyd Dinosaur Quarry's *Allosaurus fragilis* bones with the age distribution of *Canis dirus* bones from the La Brea Tar Pits in Los Angeles, California. These distributions will be based off of the standardized lengths of femora present in each locality.

As previously mentioned, most predator trap hypotheses are based on variations of the La Brea Tar Pits model, which makes it a very good source with which to compare the CLDQ in this case. The La Brea Tar Pits is a verified predator trap, with a nearly 10:1 ratio of predators to prey within the various excavated quarries; if the CLDQ is also a predator trap, its proportion should be similar. However, to simplify the equation, only a single group of predators from each quarry was examined.

In order to obtain the data needed for this study, every available (UMNH and LACMHC) femur belonging to *A. fragilis* from the CLDQ was measured in two different orientations. First the length of the bone was measured in centimeters with a large caliper parallel to the shaft of the bone as displayed in Figure 2. That value was recorded then divided in half to give the exact mid-shaft position where the second measurement, the circumference of the shaft, could be taken with a flexible tape measure. This process is based on the same method used by Madsen (1976) when he measured the same values to calculate the C:Lx100 ratio for femora excavated from the

CLDQ before 1976. Bone and cast numbers were recorded to keep the correct bones associated with their correct measurements; it was also notated whether they were left or right femora. While it is likely that some of the bones are matched pairs, it is difficult to tell which are and which are not, so every bone was included, despite the chance of doubling some measurements.

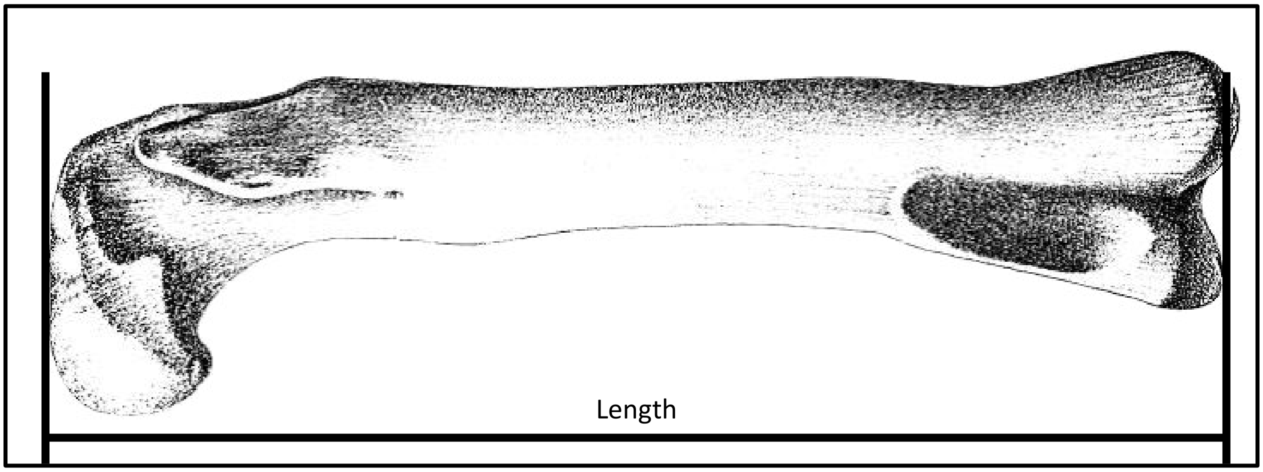


Figure 2: *Allosaurus fragilis* femur length. All femora were measured parallel to the shaft of the bone from the top of the femur head to the bottom of the distal epiphysis each measurement originally done in millimeters and converted to centimeters for analysis.

It has been previously stated in this paper that there is an estimated minimum number of 46 Allosaurs based on a count of left femora found in the quarry. Unfortunately, for this study only 34 were available for examination at the Natural History Museum of Utah in Salt Lake City, including both left and right femora, while an additional 31 femora were measured by Madsen (1976) which are included in half of the cases considered.

To compare with this data, every femur of *Canis dirus* from the La Brea Tar Pits in Los Angeles, California, was also measured in the same way as the Allosaur bones: the length was measured in centimeters with a caliper parallel to the shaft, and circumference assessed at exactly mid-shaft as shown in Figure 3. In this way 1,043 bones were measured, giving a very large data set with which to compare the Allosaur bones. Notes were taken on the bone numbers, the pits the bones were found in, if it was a left or right femur, and whether or not any damage had been done to the bones. In some cases the bones were marked as belonging to juveniles and whether or not the femur head or either of the epiphyses was unfused. This made accurate measurements of these bones harder to attain, but not impossible.

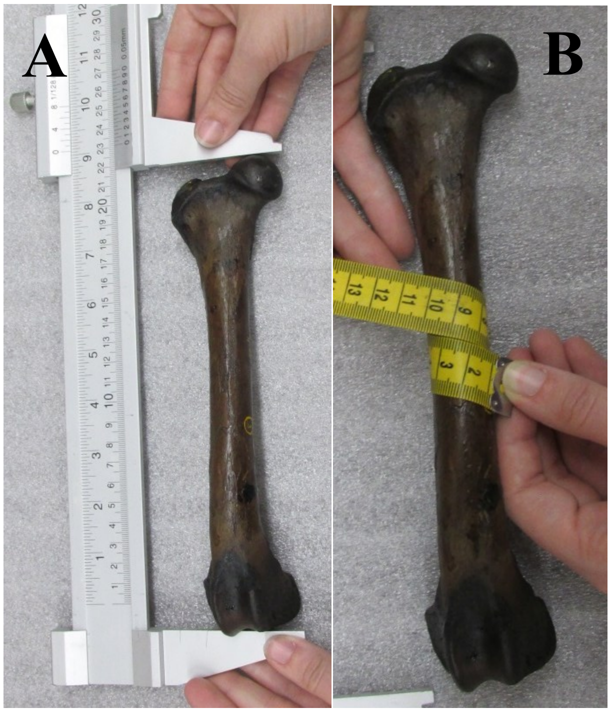


Figure 3: *Canis dirus* femur measurement methods. The caliper used to measure the length of a dire wolf femur parallel to the shaft (A) and the tape measure used to get the mid-shaft circumference of the same bone measured in centimeters.

In order to account for the length of the missing epiphyses, the entire length was measured as usual for bones that still showed the fusion line between the epiphysis and the diaphysis (as shown in Figure 4), as well as the length of each epiphysis and femur head individually. Then by measuring the length of unfused bones normally and making note of which parts were unfused, an approximate total length was attained for those bones missing pieces.

Figure 4: *Canis dirus* fusion line. The distal end of a dire wolf femur showing the line of fusion between the epiphysis and diaphysis.

While age was not directly calculated for this study, there is a direct correlation between femur size and age of an animal (Padian et al. 2001). So, while some animals may be larger than others of the same age, the overall average size-to-age correlation is sufficient to be an accurate estimate for this study. Once these values were attained and sorted into various groupings based on the location the bones were found, weather the bones were fused or not, adjusted values to account for any lack of fusion, and those compiled by other scientists, a Kolmogorov-Smirnov test could be run by Excel for the entire data set, and subsets of each individual pit compared with both the newly and previously measured *Allosaurus* femora. Comparative histograms (Figures 5-8) were produced for the scaled data, including adjusted and unadjusted wolf femur lengths.

As with any study of this nature there is a chance of errors altering the final results. In this case, special care was taken to measure each bone in the exact same fashion; however, as some elements were damaged or shaped differently (possible trauma during life or taphonomic alterations after death) than others, various differences were noted in the tables (Appendices A and B) pertaining to each bone. Hence there is a chance that the recorded data may not reflect the exact dimensions that animal may have exhibited while alive. Though not the case with the Allosaur bones, there were many unfused femora belonging to juvenile wolves found in the tar pits. An average proportion relating the shaft length to the epiphysis and femur head was attained, allowing for estimated length adjustments for those bones missing pieces due to this lack of fusion. Both the original and adjusted measurements were recorded. In order to try to control the possible errors produced by these adjustments, each individual pit (not including the three pits with only a single femur present) was compared and tested against the CLDQ bones.

Aside from bone alteration, there is a chance that some of the wolf bones may actually belong to *Canis lupus* instead of *C. dirus*. While care was taken to identify the differences between each wolf bone, given that the animals are very similar, some *C. dirus* bones may be labeled with *C. lupus* and vice versa. In the same manner, there is a chance that some of the *A. fragilis* bones may have been misidentified and not included in the data set. There is always room for error in this way; however, the likelihood of this skewing the data is very minor. Unfortunately, it is difficult to determine how the bone comparison of a bipedal dinosaur to a quadrupedal mammal might be skewed. Hence, there may be other possible errors that have not been foreseen; with that in mind, every possible step has been taken to account for these errors and correct for them when possible.

For the La Brea Tar Pits, each individual pit as well as the entire cache of bones was used to make individual and comprehensive comparisons with the Cleveland-Lloyd Dinosaur Quarry. Table 2 and Figure 5 show the lengths of all the measured bones from the CLDQ, sorted into nine different categories with a 5cm range in each category starting at 10cm and maxing out at 100cm. This is the initial information that each tar pit was compared to. Figure 6 and Table 3 show the compiled *A. fragilis* femur lengths, including those from Madsen (1976) and those shown in the previous figure and table.

The measured and corrected femur lengths of *Canis dirus* were also compiled and are shown in Figure 7(a) and Table 4. At the same time, they were also sorted into their respective pits and displayed in Table 5(a-i) and Figure 8(a-i). There were 11 pits in total and one additional group consisting of those bones found that had no information recorded with them.

Table 2

Measured CLDQ *A. fragilis* femur length distribution and frequency

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency
20-25	1	0.029	55-60	5	0.147
25-30	0	0.000	60-65	4	0.118
30-35	2	0.059	65-70	0	0.000
35-40	2	0.059	70-75	3	0.088
40-45	2	0.059	75-80	0	0.000
45-50	6	0.176	80-85	1	0.029
50-55	6	0.176	85-90	2	0.059

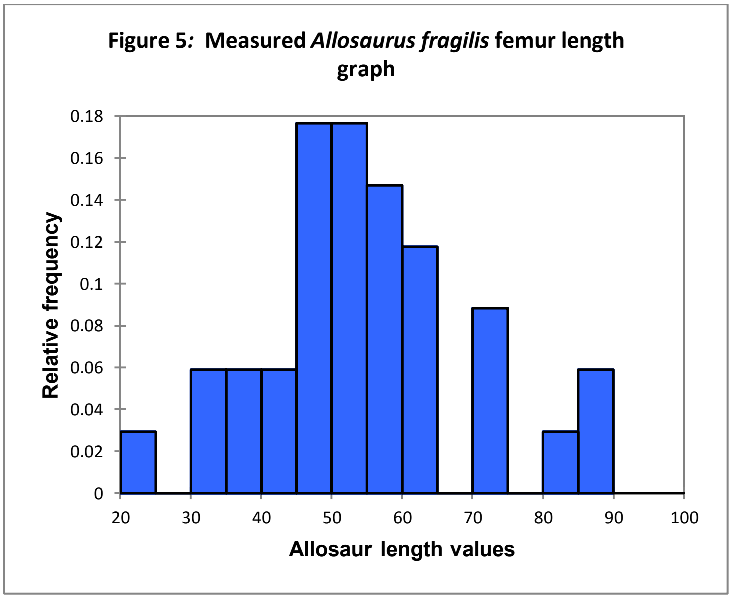


Figure 5: Measured *Allosaurus fragilis* femur length graph. The actual measured lengths of every available *A. fragilis* femur from the CLDQ, sorted by relative frequency in 10cm groups, 34 bones total.

Table 3

CLDQ total *A. fragilis* femur length distribution

Boundaries (cm)	Frequency	Relative frequency	Boundaries(cm)	Frequency	Relative Frequency
20	2	0.031	60	6	0.092
25	0	0.000	65	2	0.031
30	2	0.031	70	5	0.077
35	2	0.031	75	0	0.000
40	4	0.062	80	2	0.031
45	11	0.169	85	6	0.092
50	13	0.200	90	3	0.046
55	7	0.108			

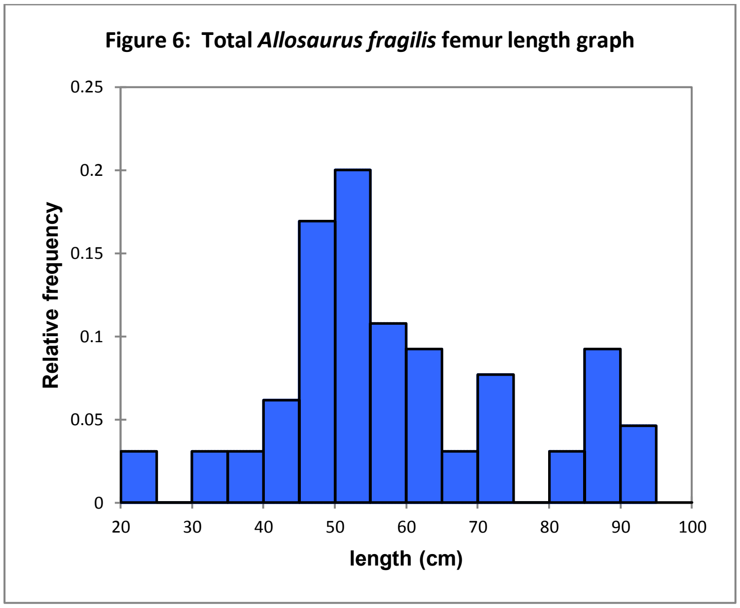


Figure 6: Total *Allosaurus fragilis* femur length graph. The distribution of both the measured *A. fragilis* femur values and those compiled by Madsen (1976), 65 bones total.

Figure 7 (a) *C. dirus* Measured Femoral Lengths

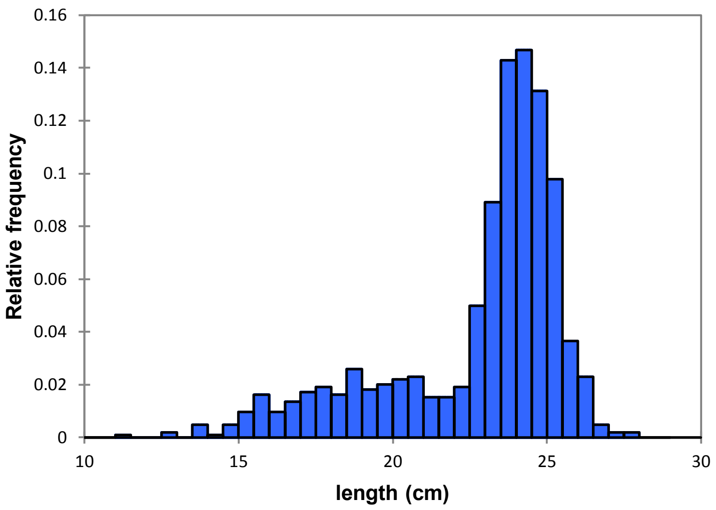


Figure 7 (b) *C. dirus* adjusted length values

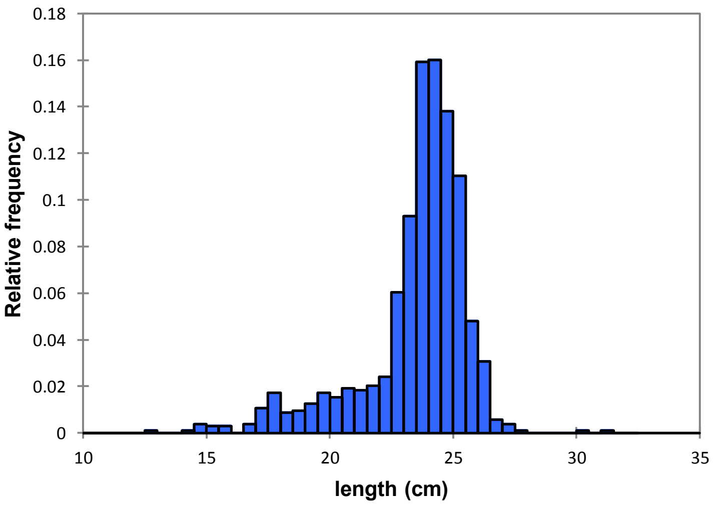
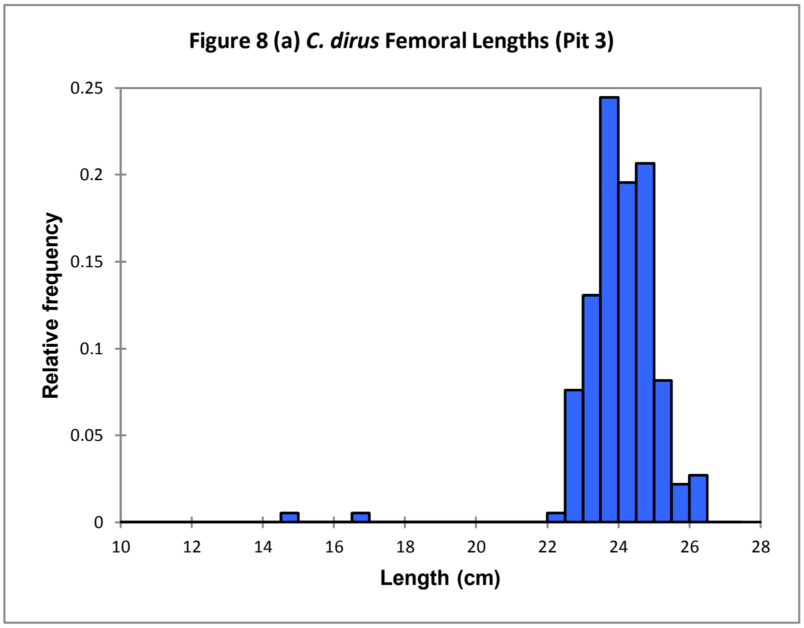


Figure 7: Measured and adjusted Canis dirus femur length graphs sorted by relative frequency in 0.5cm groups.

Table 4

C. dirus femur lengths

	Measured Values		Adjusted Values			Measured Values		Adjusted Values	
Boundaries (cm)	Frequency	Relative frequency	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Frequency	Relative Frequency
10-10.5	0	0	0	0.000	21.5-22	16	0.015	21	0.020
10.5-11	0	0	0	0.000	22-22.5	20	0.019	25	0.024
11-11.5	1	0.001	0	0.000	22.5-23	52	0.05	63	0.060
11.5-12	0	0	0	0.000	23-23.5	93	0.089	97	0.093
12-12.5	0	0	0	0.000	23.5-24	149	0.143	166	0.159
12.5-13	2	0.002	1	0.001	24-24.5	153	0.147	167	0.160
13-13.5	0	0	0	0.000	24.5-25	137	0.131	144	0.138
13.5-14	5	0.005	0	0.000	25-25.5	102	0.098	115	0.110
14-14.5	1	0.001	1	0.001	25.5-26	38	0.036	50	0.048
14.5-15	5	0.005	4	0.004	26-26.5	24	0.023	32	0.031
15-15.5	10	0.01	3	0.003	26.5-27	5	0.005	6	0.006
15.5-16	17	0.016	3	0.003	27-27.5	2	0.002	4	0.004
16-16.5	10	0.01	0	0.000	27.5-28	2	0.002	1	0.001
16.5-17	14	0.013	4	0.004	28-28.5	0	0	0	0.000
17-17.5	18	0.017	11	0.011	28.5-29	0	0	0	0.000
17.5-18	20	0.019	18	0.017	29-29.5	0	0	0	0.000
18-18.5	17	0.016	9	0.009	29.5-30	0	0	0	0.000
18.5-19	27	0.026	10	0.010	30-30.5	0	0	1	0.001
19-19.5	19	0.018	13	0.012	30.5-31	0	0	0	0.000
19.5-20	21	0.02	18	0.017	31-31.5	0	0	1	0.001
20-20.5	23	0.022	16	0.015	31.5-32	0	0	0	0.000
20.5-21	24	0.023	20	0.019	32-32.5	0	0	0	0.000
21-21.5	16	0.015	19	0.018					



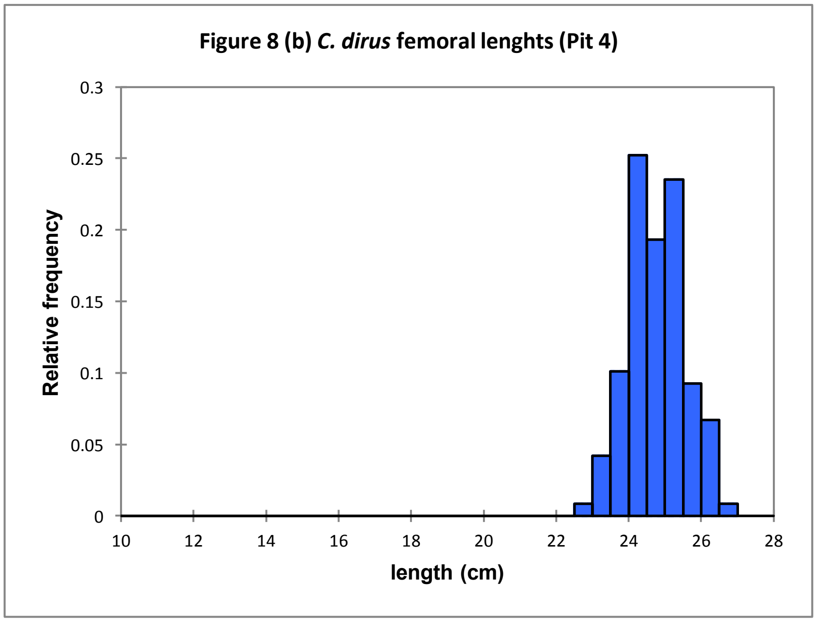


Figure 8: Canis dirus adjusted femur lengths divided into individual pits (continued on following page).

Figure 8 (c) *C. dirus* femoral lengths (Pit 13)

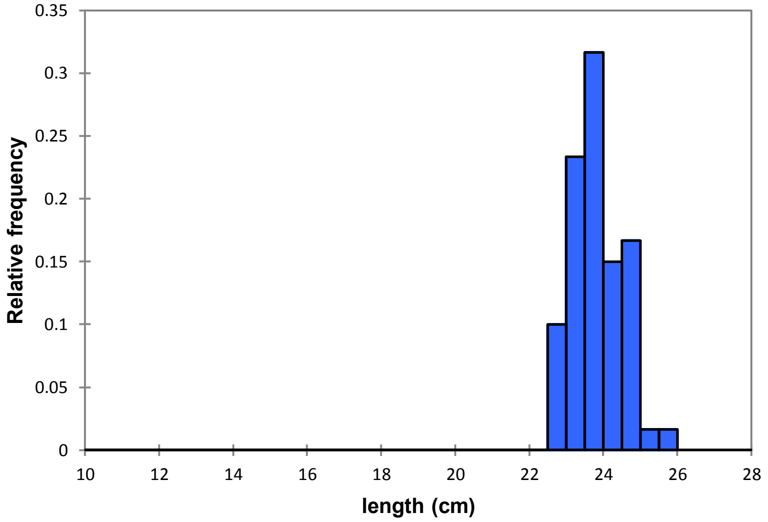


Figure 8 (d) *C. dirus* femoral lengths (Pit 61)

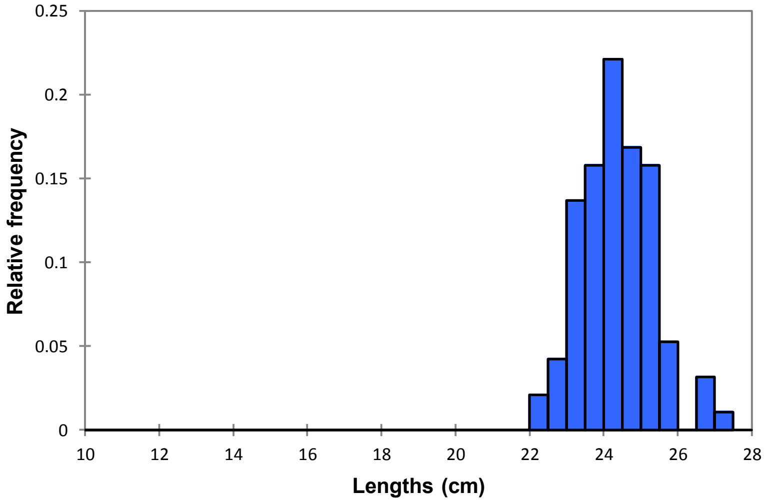


Figure 8 (continued)

Figure 8 (e) *C. dirus* Femoral lenghts (Pit 60)

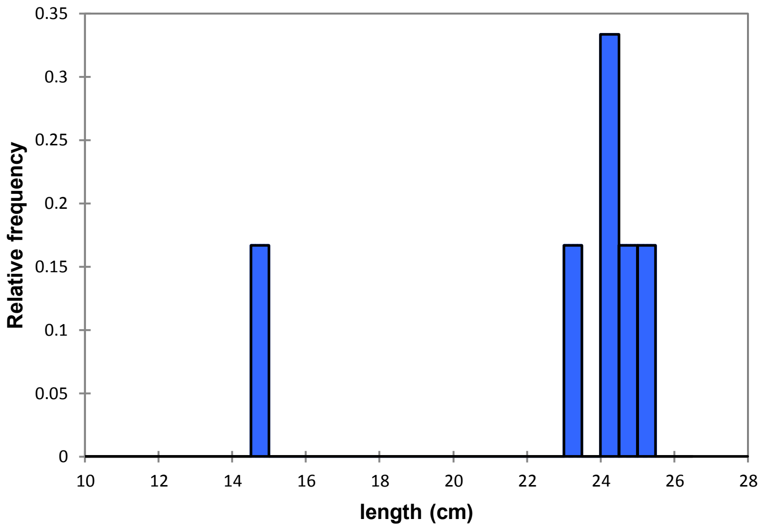


Figure 8 (f) *C. dirus* femoral lengths (Pit 67)

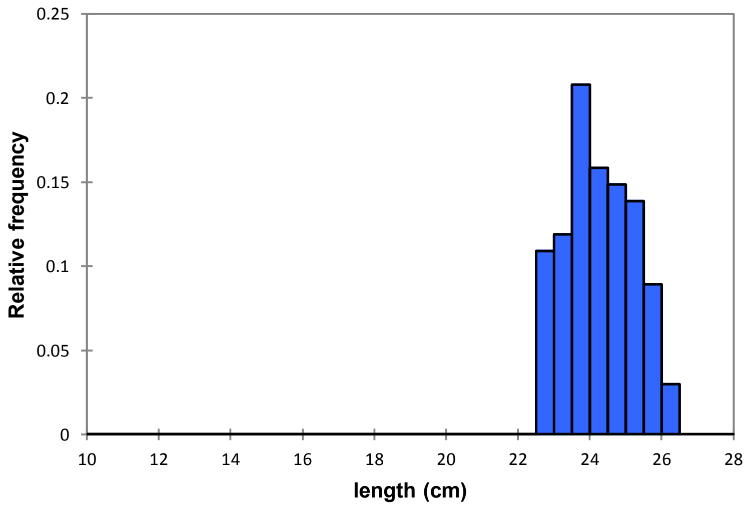
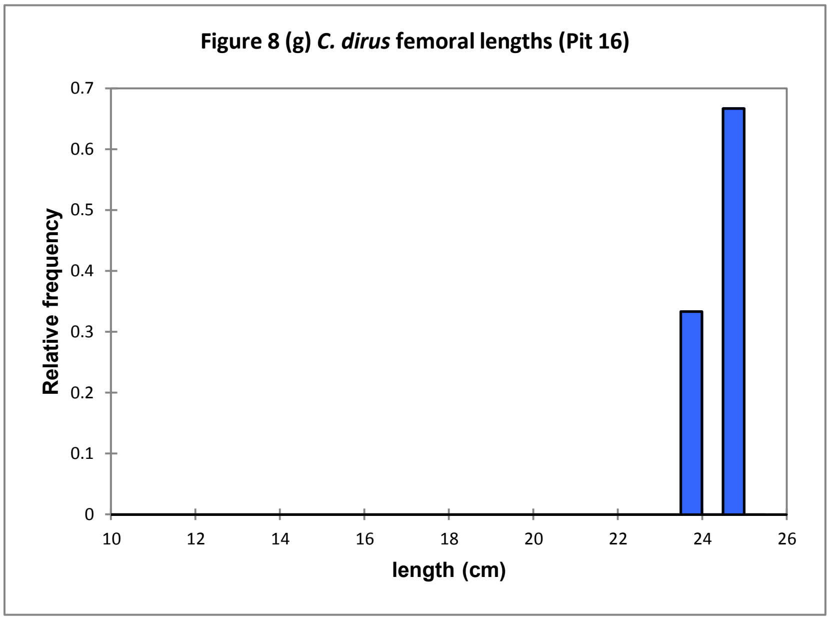


Figure 8 (continued)



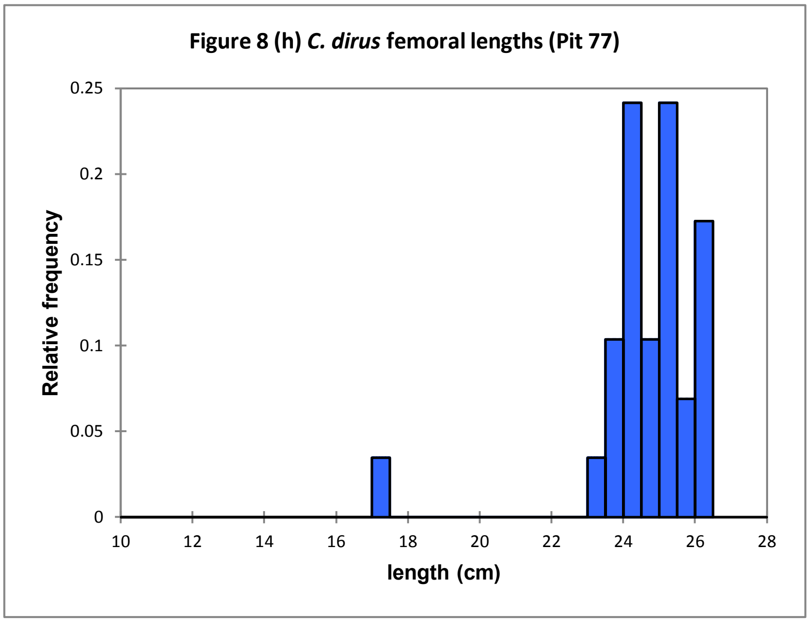


Figure 8 (continued)

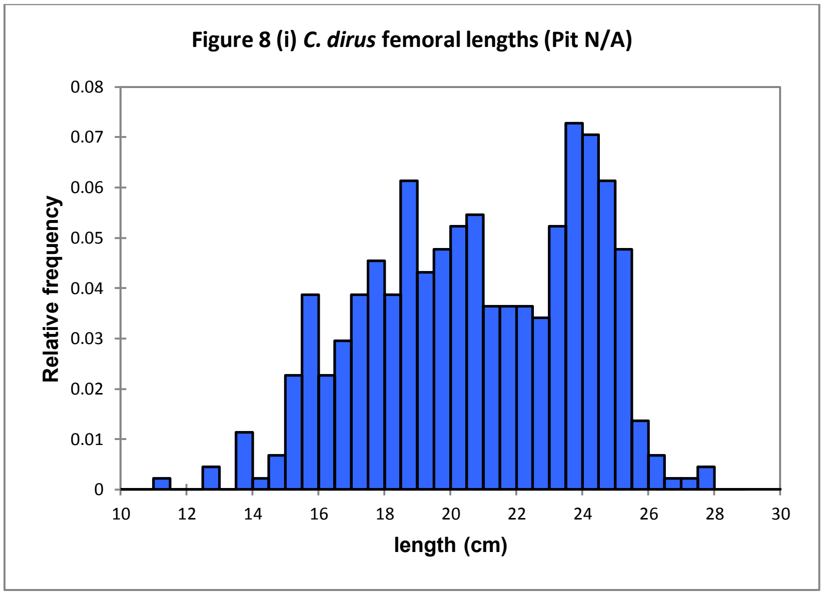


Figure 8 (continued)

Table 5

C. dirus femur length distribution by pit

Table 5(a): Pit 3

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative frequency
10-10.5	0	0.000	16-16.5	0	0.000	22-22.5	1	0.005
10.5-11	0	0.000	16.5-17	1	0.005	22.5-23	14	0.076
11-11.5	0	0.000	17-17.5	0	0.000	23-23.5	24	0.130
11.5-12	0	0.000	17.5-18	0	0.000	23.5-24	45	0.245
12-12.5	0	0.000	18-18.5	0	0.000	24-24.5	36	0.196
12.5-13	0	0.000	18.5-19	0	0.000	24.5-25	38	0.207
13-13.5	0	0.000	19-19.5	0	0.000	25-25.5	15	0.082
13.5-14	0	0.000	19.5-20	0	0.000	25.5-26	4	0.022
14-14.5	0	0.000	20-20.5	0	0.000	26-26.5	5	0.027
14.5-15	1	0.005	20.5-21	0	0.000	26.5-27	0	0.000
15-15.5	0	0.000	21-21.5	0	0.000	27-27.5	0	0.000
15.5-16	0	0.000	21.5-22	0	0.000			

Table 5(b): Pit 4

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	16-16.5	0	0.000	21.5-22	0	0.000
10.5-11	0	0.000	16.5-17	0	0.000	22-22.5	0	0.000
11-11.5	0	0.000	17-17.5	0	0.000	22.5-23	1	0.008
11.5-12	0	0.000	17.5-18	0	0.000	23-23.5	5	0.042
12-12.5	0	0.000	18-18.5	0	0.000	23.5-24	12	0.101
12.5-13	0	0.000	18.5-19	0	0.000	24-24.5	30	0.252
13-13.5	0	0.000	19-19.5	0	0.000	24.5-25	23	0.193
13.5-14	0	0.000	19.5-20	0	0.000	25-25.5	28	0.235
14-14.5	0	0.000	20-20.5	0	0.000	25.5-26	11	0.092
14.5-15	0	0.000	20.5-21	0	0.000	26-26.5	8	0.067
15-15.5	0	0.000	21-21.5	0	0.000	26.5-27	1	0.008
15.5-16	0	0.000						

Table 5(c): Pit 13

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
10-10.5	0	0.000	15.5-16	0	0.000	21-21.5	0	0.000
10.5-11	0	0.000	16-16.5	0	0.000	21.5-22	0	0.000
11-11.5	0	0.000	16.5-17	0	0.000	22-22.5	0	0.000
11.5-12	0	0.000	17-17.5	0	0.000	22.5-23	6	0.100
12-12.5	0	0.000	17.5-18	0	0.000	23-23.5	14	0.233
12.5-13	0	0.000	18-18.5	0	0.000	23.5-24	19	0.317
13-13.5	0	0.000	18.5-19	0	0.000	24-24.5	9	0.150
13.5-14	0	0.000	19-19.5	0	0.000	24.5-25	10	0.167
14-14.5	0	0.000	19.5-20	0	0.000	25-25.5	1	0.017
14.5-15	0	0.000	20-20.5	0	0.000	25.5-26	1	0.017
15-15.5	0	0.000	20.5-21	0	0.000			

Table 5(d): Pit 61

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	16-16.5	0	0.000	22-22.5	2	0.021
10.5-11	0	0.000	16.5-17	0	0.000	22.5-23	4	0.042
11-11.5	0	0.000	17-17.5	0	0.000	23-23.5	13	0.137
11.5-12	0	0.000	17.5-18	0	0.000	23.5-24	15	0.158
12-12.5	0	0.000	18-18.5	0	0.000	24-24.5	21	0.221
12.5-13	0	0.000	18.5-19	0	0.000	24.5-25	16	0.168
13-13.5	0	0.000	19-19.5	0	0.000	25-25.5	15	0.158
13.5-14	0	0.000	19.5-20	0	0.000	25.5-26	5	0.053
14-14.5	0	0.000	20-20.5	0	0.000	26-26.5	0	0.000
14.5-15	0	0.000	20.5-21	0	0.000	26.5-27	3	0.032
15-15.5	0	0.000	21-21.5	0	0.000	27-27.5	1	0.011
15.5-16	0	0.000	21.5-22	0	0.000			

Table 5(e): Pit 60

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	15.5-16	0	0.000	21-21.5	0	0.000
10.5-11	0	0.000	16-16.5	0	0.000	21.5-22	0	0.000
11-11.5	0	0.000	16.5-17	0	0.000	22-22.5	0	0.000
11.5-12	0	0.000	17-17.5	0	0.000	22.5-23	0	0.000
12-12.5	0	0.000	17.5-18	0	0.000	23-23.5	1	0.167
12.5-13	0	0.000	18-18.5	0	0.000	23.5-24	0	0.000
13-13.5	0	0.000	18.5-19	0	0.000	24-24.5	2	0.333
13.5-14	0	0.000	19-19.5	0	0.000	24.5-25	1	0.167
14-14.5	0	0.000	19.5-20	0	0.000	25-25.5	1	0.167
14.5-15	1	0.167	20-20.5	0	0.000	25.5-26	0	0.000
15-15.5	0	0.000	20.5-21	0	0.000	26-26.5	0	0.000

Table 5(f): Pit 16

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	15.5-16	0	0.000	20.5-21	0	0.000
10.5-11	0	0.000	16-16.5	0	0.000	21-21.5	0	0.000
11-11.5	0	0.000	16.5-17	0	0.000	21.5-22	0	0.000
11.5-12	0	0.000	17-17.5	0	0.000	22-22.5	0	0.000
12-12.5	0	0.000	17.5-18	0	0.000	22.5-23	0	0.000
12.5-13	0	0.000	18-18.5	0	0.000	23-23.5	0	0.000
13-13.5	0	0.000	18.5-19	0	0.000	23.5-24	2	0.333
13.5-14	0	0.000	19-19.5	0	0.000	24-24.5	0	0.000
14-14.5	0	0.000	19.5-20	0	0.000	24.5-25	4	0.667
14.5-15	0	0.000	20-20.5	0	0.000	25-25.5	0	0.000
15-15.5	0	0.000						

Table 5(g): Pit 67

Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	15.5-16	0	0.000	21-21.5	0	0.000
10.5-11	0	0.000	16-16.5	0	0.000	21.5-22	0	0.000
11-11.5	0	0.000	16.5-17	0	0.000	22-22.5	0	0.000
11.5-12	0	0.000	17-17.5	0	0.000	22.5-23	11	0.109
12-12.5	0	0.000	17.5-18	0	0.000	23-23.5	12	0.119
12.5-13	0	0.000	18-18.5	0	0.000	23.5-24	21	0.208
13-13.5	0	0.000	18.5-19	0	0.000	24-24.5	16	0.158
13.5-14	0	0.000	19-19.5	0	0.000	24.5-25	15	0.149
14-14.5	0	0.000	19.5-20	0	0.000	25-25.5	14	0.139
14.5-15	0	0.000	20-20.5	0	0.000	25.5-26	9	0.089
15-15.5	0	0.000	20.5-21	0	0.000	26-26.5	3	0.030

Table 5(h): Pit 77

Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	15.5-16	0	0.000	21-21.5	0	0.000
10.5-11	0	0.000	16-16.5	0	0.000	21.5-22	0	0.000
1111.5	0	0.000	16.5-17	0	0.000	22-22.5	0	0.000
11.5-12	0	0.000	17-17.5	1	0.034	22.5-23	0	0.000
12-12.5	0	0.000	17.5-18	0	0.000	23-23.5	1	0.034
12.5-13	0	0.000	18-18.5	0	0.000	23.5-24	3	0.103
13-13.5	0	0.000	18.5-19	0	0.000	24-24.5	7	0.241
13.5-14	0	0.000	19-19.5	0	0.000	24.5-25	3	0.103
14-14.5	0	0.000	19.5-20	0	0.000	25-25.5	7	0.241
14.5-15	0	0.000	20-20.5	0	0.000	25.5-26	2	0.069
15-15.5	0	0.000	20.5-21	0	0.000	26-26.5	5	0.172

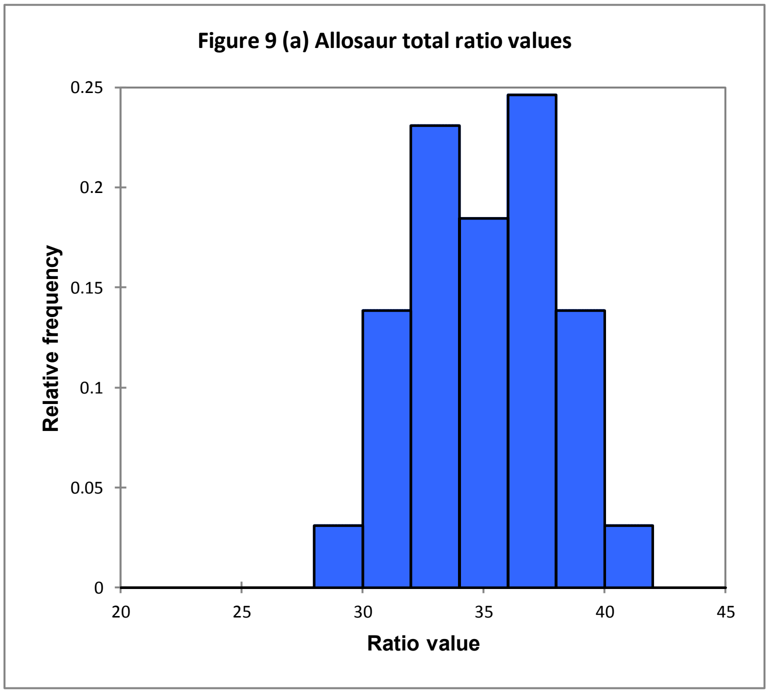
Table 5(i): Pit N/A

Bound (cm)	Frequency	Relative frequency	Boundaries (cm)	Frequency	Relative Frequency	Boundaries (cm)	Frequency	Relative Frequency
10-10.5	0	0.000	16.5-17	13	0.030	23-23.5	23	0.052
10.5-11	0	0.000	17-17.5	17	0.039	23.5-24	32	0.073
11-11.5	1	0.002	17.5-18	20	0.045	24-24.5	31	0.070
11.5-12	0	0.000	18-18.5	17	0.039	24.5-25	27	0.061
12-12.5	0	0.000	18.5-19	27	0.061	25-25.5	21	0.048
12.5-13	2	0.005	19-19.5	19	0.043	25.5-26	6	0.014
13-13.5	0	0.000	19.5-20	21	0.048	26-26.5	3	0.007
13.5-14	5	0.011	20-20.5	23	0.052	26.5-27	1	0.002
14-14.5	1	0.002	20.5-21	24	0.055	27-27.5	1	0.002
14.5-15	3	0.007	21-21.5	16	0.036	27.5-28	2	0.005
15-15.5	10	0.023	21.5-22	16	0.036	28-28.5	0	0.000
15.5-16	17	0.039	22-22.5	16	0.036	28.5-29	0	0.000
16-16.5	10	0.023						

The original femur lengths were also compared relative to their respective mid-shaft circumferences to find the C:Lx100 ratio by the following equation:

$$\frac{Circumference}{Length} \cdot 100 = ratio$$

These raw values for both *A. fragilis* and *C. dirus* can be seen in the Appendices A and B, and the distributions of those values can be seen in Figure 9(a) and 9(b) and Table 6.



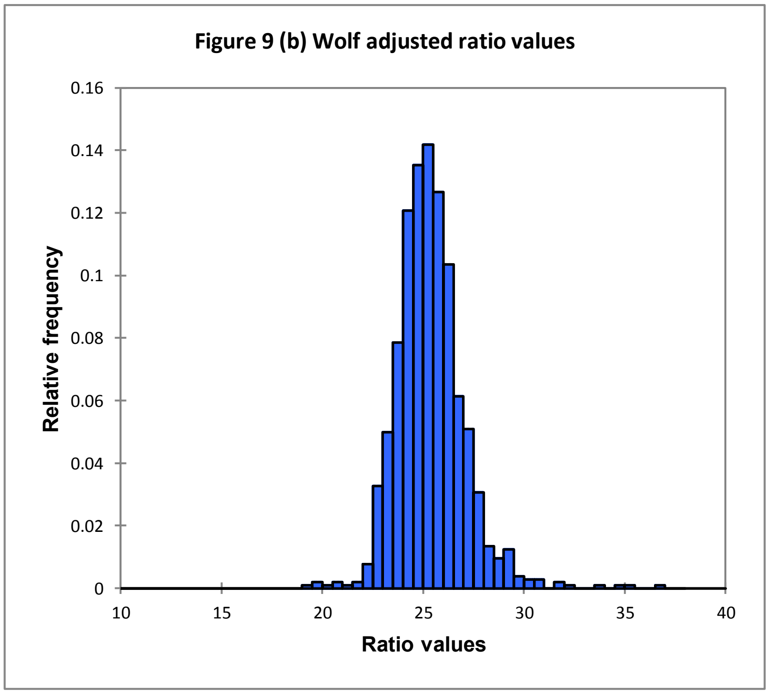


Figure 9: Femur ratio side-by-side comparison for *A. fragilis* and *C. dirus*. (a)The total ratio values of *A. fragilis* compiled from those measured and those collected by Madsen (1976). And (b) the total ratio values after computations were made to correct for the lack of epiphysis on some femora of *C. dirus*.

Table 6 (a)

A. fragilis femur ratio distribution

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
20-22	0	0.000	32-34	15	0.231
22-24	0	0.000	34-36	12	0.185
24-26	0	0.000	36-38	16	0.246
26-28	0	0.000	38-40	9	0.138
28-30	2	0.031	40-42	2	0.031
30-32	9	0.138			

Table 6 (b)

C. dirus femur ratio distribution

Boundaries	Frequency	Relativefrequency	Boundaries	Frequency	Relative Frequency	Boundaries	Frequency	Relative Frequency
10-10.5	0	0.000	19.5-20	2	0.002	29-29.5	13	0.012
10.5-11	0	0.000	20-20.5	1	0.001	29.5-30	4	0.004
11-11.5	0	0.000	20.5-21	2	0.002	30-30.5	3	0.003
11.5-12	0	0.000	21-21.5	1	0.001	30.5-31	3	0.003
12-12.5	0	0.000	21.5-22	2	0.002	31-31.5	0	0.000
12.5-13	0	0.000	22-22.5	8	0.008	31.5-32	2	0.002
13-13.5	0	0.000	22.5-23	34	0.033	32-32.5	1	0.001
13.5-14	0	0.000	23-23.4	52	0.050	32.5-33	0	0.000
14-14.5	0	0.000	23.5-24	82	0.079	33-33.5	0	0.000
14.5-15	0	0.000	24-24.5	126	0.121	33.5-34	1	0.001
15-15.5	0	0.000	24.5-25	141	0.135	34-34.5	0	0.000
15.5-16	0	0.000	25-25.5	148	0.142	34.5-35	1	0.001
16-16.5	0	0.000	25.5-26	132	0.127	35-35.5	1	0.001
16.5-17	0	0.000	26-26.5	108	0.104	35.5-36	0	0.000
17-17.5	0	0.000	26.5-27	64	0.061	36-36.5	0	0.000
17.5-18	0	0.000	27-27.5	53	0.051	36.5-37	1	0.001
18-18.5	0	0.000	27.5-28	32	0.031	37-37.5	0	0.000
18.5-19	0	0.000	28-28.5	14	0.013	37.5-38	0	0.000
19-19.5	1	0.001	28.5-29	10	0.010			

It was previously mentioned that there were some bones from the La Brea Tar Pits that had not experienced fusion of either epiphyses, thus slightly skewing the data from that location. It was noted in each of the previous graphs and tables whether the original or adjusted data was used in an attempt to minimize this offset.

Finally, all of the previously mentioned femur length values, with their corresponding distributions and graphs, were standardized and compiled in Figure 10 and Table 7 for *A. fragilis* and Figure 11 and Table 8 for the total counts of *C. dirus* and Figure 12(a-g) and Tables 9(a-g) for the individual pits of *C. dirus*.

Table 7

A. fragilis standardized femur length values

	Measured values		Total Values	
Boundaries	Frequency	Relative frequency	Frequency	Relative frequency
-3 to -2.5	0	0.000	0	0.000
-2.5 to -2	1	0.029	2	0.031
-2 to -1.5	0	0.000	1	0.015
-1.5 to -1	3	0.088	5	0.077
-1 to -0.5	8	0.235	13	0.200
-0.5 to 0	7	0.206	17	0.262
0 to 0.5	6	0.176	10	0.154
0.5 to 1	3	0.088	6	0.092
1 to 1.5	3	0.088	1	0.015
1.5 to 2	1	0.029	10	0.154
2 to 2.5	2	0.059	0	0.000

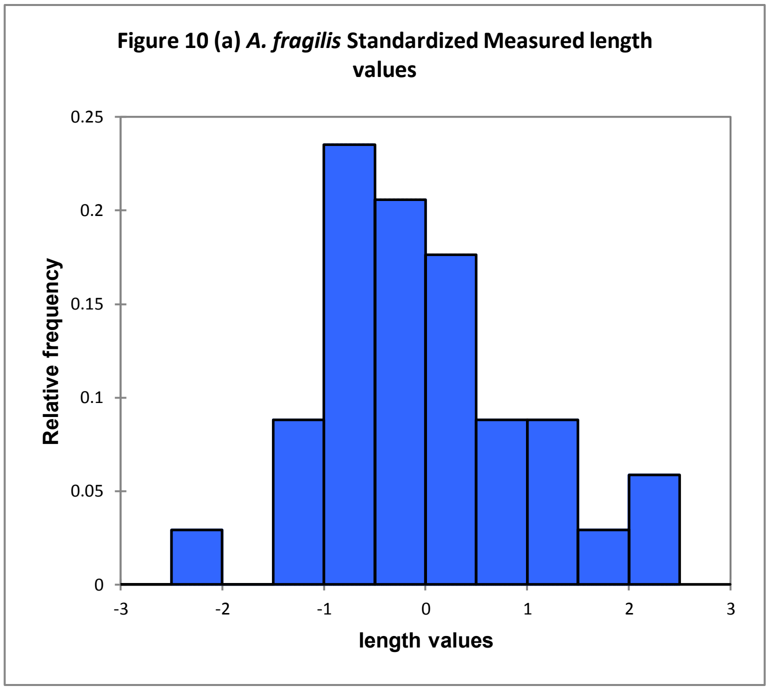


Figure 10 (a) ***A. fragilis*** **Standardized Measured length values**

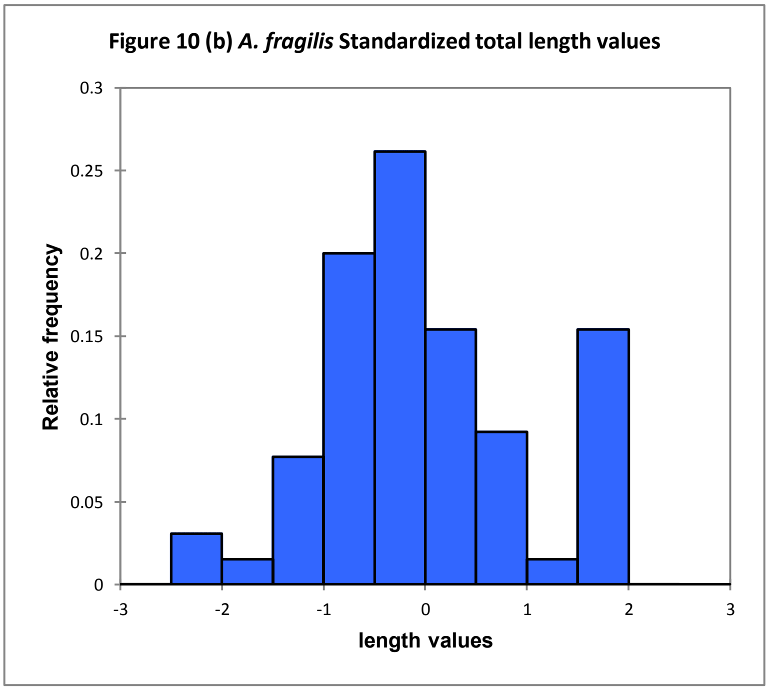


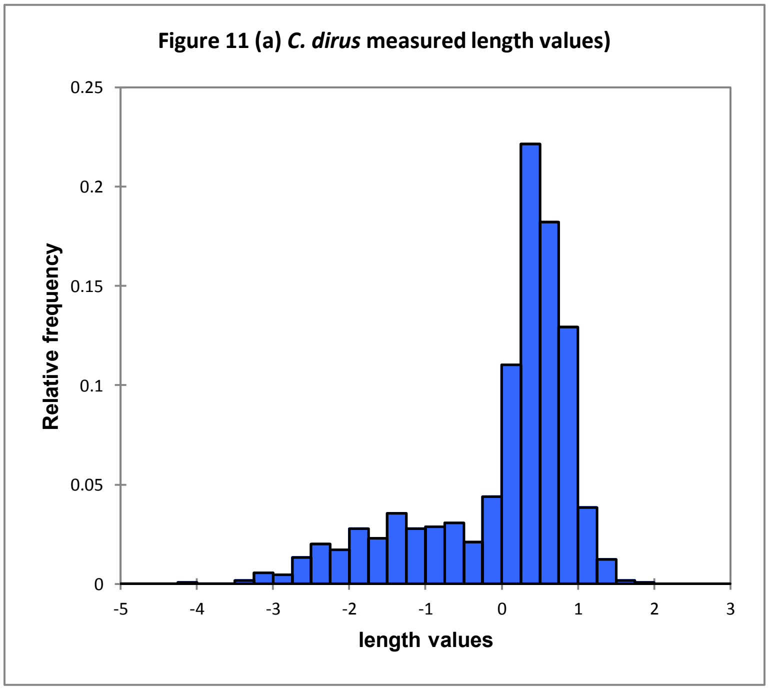
Figure 10 (b) ***A. fragilis*** **Standardized total length values**

Figure 10: Standardized measured and total femur lengths of *A. fragilis.*

Table 8

C. dirus standardized femur length counts

	Measured values		Adjusted Values			Measured Values		Adjusted Values	
Boundaries	Frequency	Relative frequency	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency	Frequency	Relative Frequency
-5 to -4.75	0	0.000	1	0.001	-0.5 to -0.25	22	0.021	61	0.058
-4.75 to -4.5	0	0.000	0	0.000	-0.25 to 0	46	0.044	107	0.103
-4.5 to -4.25	0	0.000	0	0.000	0 to 0.25	115	0.110	178	0.171
-4.25 to-4	1	0.001	4	0.004	0.25 to 0.5	231	0.221	183	0.175
-4 to-3.75	0	0.000	1	0.001	0.5 to 0.75	190	0.182	155	0.149
-3.75 to-3.5	0	0.000	5	0.005	0.75 to 1	135	0.129	105	0.101
-3.5 to -3.25	2	0.002	1	0.001	1 to 1.25	40	0.038	37	0.035
-3.25 to -3	6	0.006	3	0.003	1.25 to 1.5	13	0.012	19	0.018
-3 to -2.75	5	0.005	12	0.012	1.5 to 1.75	2	0.002	7	0.007
-2.75 to -2.5	14	0.013	14	0.013	1.75 to 2	1	0.001	1	0.001
-2.5 to -2.25	21	0.020	13	0.012	2 to 2.25	0	0.000	0	0.000
-2.25 to -2	18	0.017	13	0.012	2.25 to 2.5	0	0.000	0	0.000
-2 to -1.75	29	0.028	17	0.016	2.5to 2.75	0	0.000	0	0.000
-1.75 to -1.5	24	0.023	14	0.013	2.75 to 3	0	0.000	0	0.000
-1.5 to -1.25	37	0.035	23	0.022	3 to 3.25	0	0.000	1	0.001
-1.25 to -1	29	0.028	19	0.018	3.25 to 2.5	0	0.000	0	0.000
-1 to -0.75	30	0.029	25	0.024	3.5 to 3.75	0	0.000	1	0.001
-0.75 to -0.5	32	0.031	23	0.022					



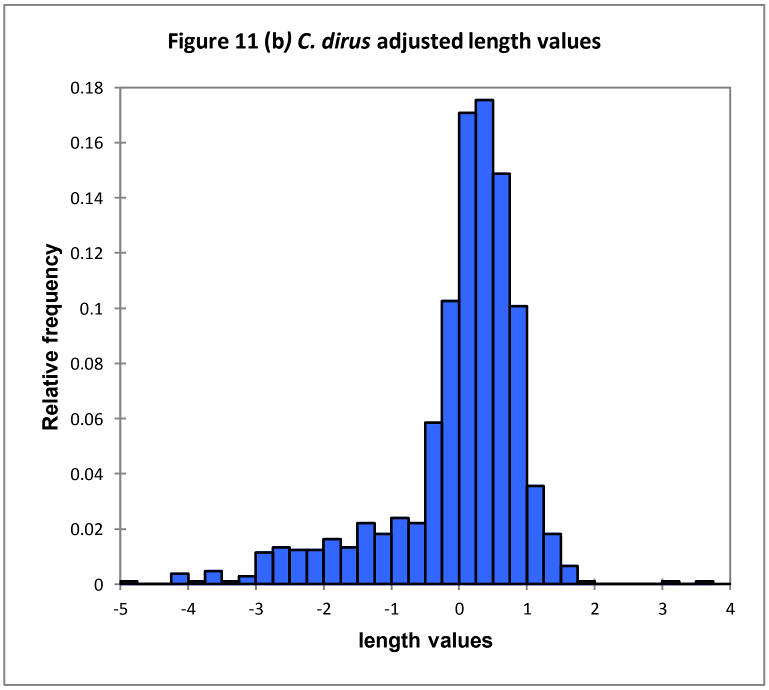


Figure 11: Standardized measured and adjusted femur lengths of *C. dirus.*

Table 9
C. dirus standardized femur length distribution by pit

Table 9(a): Pit 3

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency	Boundaries	Frequency	Relative Frequency
-8 to -7.75	1	0.005	-4.5 to -4.25	0	0.000	-1 to -0.75	14	0.076
-7.75 to -7.5	0	0.000	-4.25 to -4	0	0.000	-0.75 to -0.5	16	0.087
-7.5 to -7.25	0	0.000	-4 to -3.75	0	0.000	-0.5 to -0.25	29	0.158
-7.25 to -7	0	0.000	-3.75 to -3.5	0	0.000	-0.25 to 0	23	0.125
-7 to -6.75	0	0.000	-3.5 to -3.25	0	0.000	0 to 0.25	17	0.092
-6.75 to -6.5	0	0.000	-3.25 to -3	0	0.000	0.25 to 0.5	29	0.158
-6.5 to -6.25	0	0.000	-3 to -2.75	0	0.000	0.5 to 0.75	17	0.092
-6.25 to -6	1	0.005	-2.75 to -2.5	0	0.000	0.75 to 1	16	0.087
-6 to -5.75	0	0.000	-2.5 to -2.25	0	0.000	1 to 1.25	5	0.027
-5.75 to -5.5	0	0.000	-2.25 to -2	0	0.000	1.25 to 1.25	2	0.011
-5.5 to -5.25	0	0.000	-2 to -1.75	0	0.000	1.5 to 1.75	3	0.016
-5.25 to -5	0	0.000	-1.75 to -1.5	1	0.005	1.75 to 2	3	0.016
-5 to -4.75	0	0.000	-1.5 to -1.25	0	0.000	2 to 2.25	0	0.000
-4.75 to -4.5	0	0.000	-1.25 to -1	7	0.038			

Table 9(b): Pit 4

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-3 to -2.75	0	0.000	-0.25 to 0	9	0.076
-2.75 to -2.5	1	0.008	0 to 0.25	6	0.050
-2.5 to -2.25	0	0.000	0.25 to 0.5	14	0.118
-2.25 to -2	0	0.000	0.5 to 0.75	13	0.109
-2 to -1.75	1	0.008	0.75 to 1	11	0.092
-1.75 to -1.5	6	0.050	1 to 1.25	4	0.034
-1.5 to -1.25	3	0.025	1.25 to 1.5	2	0.017
-1.25 to -1	7	0.059	1.5 to 1.75	2	0.017
-1 to -0.75	10	0.084	1.75 to 2	3	0.025
-0.75 to -0.5	14	0.118	2 to 2.25	4	0.034
-0.5 to -0.25	9	0.076	2.25 to 2.5	0	0.000

Table 9(c): Pit 13

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-2 to -1.75	2	0.033	0.5 to 0.75	3	0.050
-1.75 to -1.5	2	0.033	0.75 to 1	1	0.017
-1.5 to -1.25	0	0.000	1 to 1.25	5	0.083
-1.25 to -1	7	0.117	1.25 to 1.5	1	0.017
-1 to -0.75	2	0.033	1.5 to 1.75	4	0.067
-0.75 to -0.5	6	0.100	1.75 to 2	1	0.017
-0.5 to -0.25	7	0.117	2 to 2.25	0	0.000
-0.25 to 0	8	0.133	2.25 to 2.5	0	0.000
0 to 0.25	5	0.083	2.5 to 2.75	1	0.017
0.25 to 0.5	5	0.083			

Table 9(d): Pit 61

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-3 to -2.75	0	0.000	0 to 0.25	9	0.095
-2.75 to -2.5	0	0.000	0.25 to 0.5	7	0.074
-2.5 to -2.25	0	0.000	0.5 to 0.75	8	0.084
-2.25 to -2	1	0.011	0.75 to 1	6	0.063
-2 to -1.75	3	0.032	1 to 1.25	9	0.095
-1.75 to -1.5	2	0.021	1.25 to 1.5	2	0.021
-1.5 to -1.25	1	0.011	1.5 to 1.75	0	0.000
-1.25 to -1	6	0.063	1.75 to 2	0	0.000
-1 to -0.75	11	0.116	2 to 2.25	0	0.000
-0.75 to -0.5	7	0.074	2.25 to 2.5	2	0.021
-0.5 to -0.25	10	0.105	2.5 to 2.75	1	0.011
-0.25 to 0	9	0.095	2.75 to 3	1	0.011

Table 9(e): Pit 67

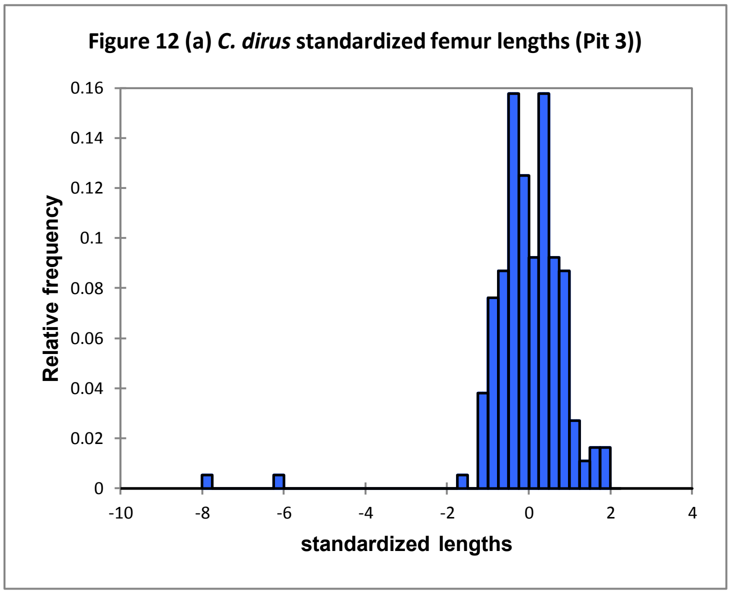
Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-2 to -1.75	2	0.020	0.25 to 0.5	4	0.040
-1.75 to -1.5	5	0.050	0.5 to 0.75	11	0.109
-1.5 to -1.25	4	0.040	0.75 to 1	9	0.089
-1.25 to -1	4	0.040	1 to 1.25	4	0.040
-1 to -0.75	12	0.119	1.25 to 1.5	3	0.030
-0.75 to -0.5	9	0.089	1.5 to 1.75	5	0.050
-0.5 to -0.25	10	0.099	1.75 to 2	5	0.050
-0.25 to 0	10	0.099	2 to 2.25	0	0.000
0 to 0.25	4	0.040			

Table 9(f): Pit 77

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-5 to -4.75	0	0.000	-1.75 to -1.5	0	0.000
-4.75 to -4.5	0	0.000	-1.5 to -1.25	0	0.000
-4.5 to -4.25	1	0.034	-1.25 to -1	0	0.000
-4.25 to -4	0	0.000	-1 to -0.75	1	0.034
-4 to -3.75	0	0.000	-0.75 to -0.5	0	0.000
-3.75 to -3.5	0	0.000	-0.5 to -0.25	8	0.276
-3.5 to -3.25	0	0.000	-0.25 to 0	3	0.103
-3.25 to -3	0	0.000	0 to 0.25	3	0.103
-3 to -2.75	0	0.000	0.25 to 0.5	6	0.207
-2.75 to -2.5	0	0.000	0.5 to 0.75	2	0.069
-2.5 to -2.25	0	0.000	0.75 to 1	3	0.103
-2.25 to -2	0	0.000	1 to 1.25	2	0.069
-2 to -1.75	0	0.000			

Table 9(g): Pit N/A

Boundaries	Frequency	Relative frequency	Boundaries	Frequency	Relative Frequency
-4 to -3.75	0	0.000	-0.25 to 0	28	0.064
-3.75 to -3.5	1	0.002	0 to 0.25	36	0.082
-3.5 to -3.25	0	0.000	0.25 to 0.5	56	0.127
-3.25 to -3	0	0.000	0.5 to 0.75	60	0.136
-3 to -2.75	3	0.007	0.75 to 1	50	0.114
-2.75 to -2.5	3	0.007	1 to 1.25	33	0.075
-2.5 to -2.25	3	0.007	1.25 to 1.5	14	0.032
-2.25 to 2	2	0.005	1.5 to 1.75	4	0.009
-2 to -1.75	15	0.034	1.75 to 2	2	0.005
-1.75 to -1.5	19	0.043	2 to 2.25	0	0.000
-1.5 to -1.25	12	0.027	2.25 to 2.5	0	0.000
-1.25 to -1	22	0.050	2.5 to 2.75	0	0.000
-1 to -0.75	22	0.050	2.75 to 3	1	0.002
-0.75 to -0.5	25	0.057	3 to 3.25	1	0.002
-0.5 to -0.25	28	0.064	3.25 to 3.5	0	0.000



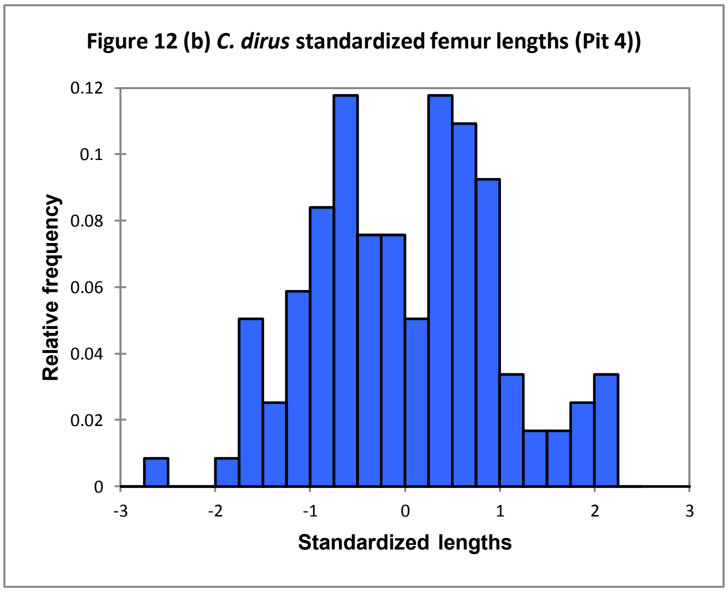


Figure 12 (a-g): Standardized *C. dirus* femur lengths separated into individual pits. This excludes Pits 9, 60, 16, 90, and 91,which all contained less than six bones in each (continued on following page).

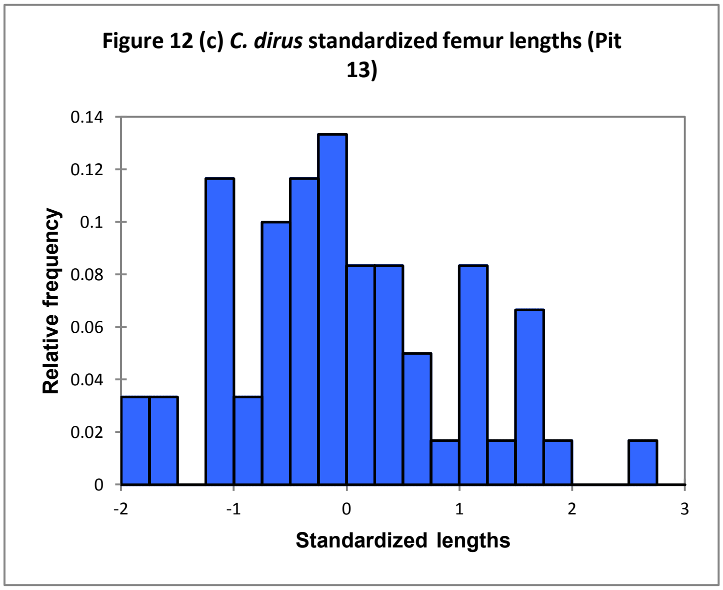


Figure 12 (c) *C. dirus* standardized femur lengths (Pit 13)

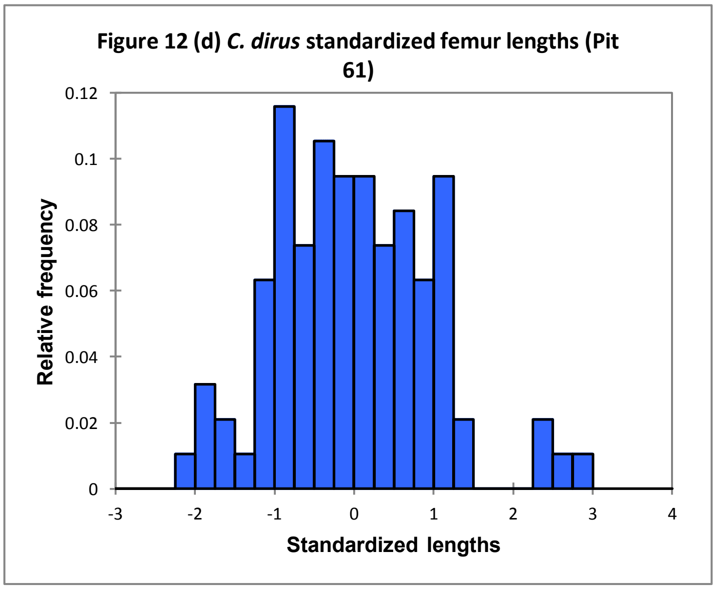


Figure 12 (d) *C. dirus* standardized femur lengths (Pit 61)

Figure 12 (continued)

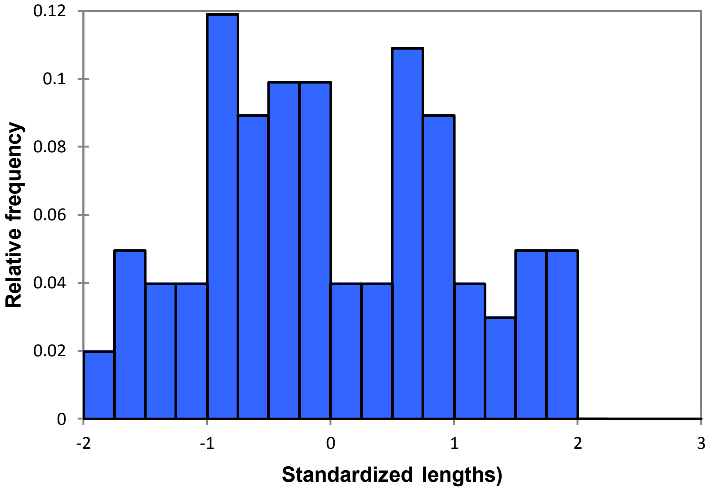


Figure 12 (e) ***C. dirus*** **standardized femur lengths (Pit 67))**

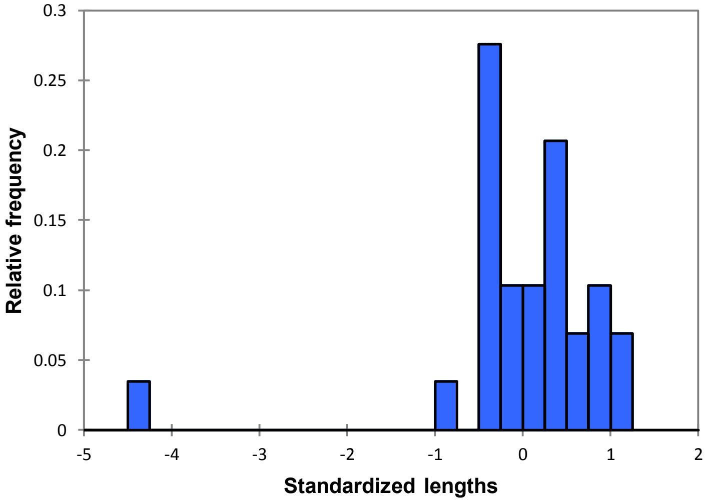


Figure 12 (f*) C. dirus* **standardized femur lengths (Pit 77))**

Figure 12 (continued)

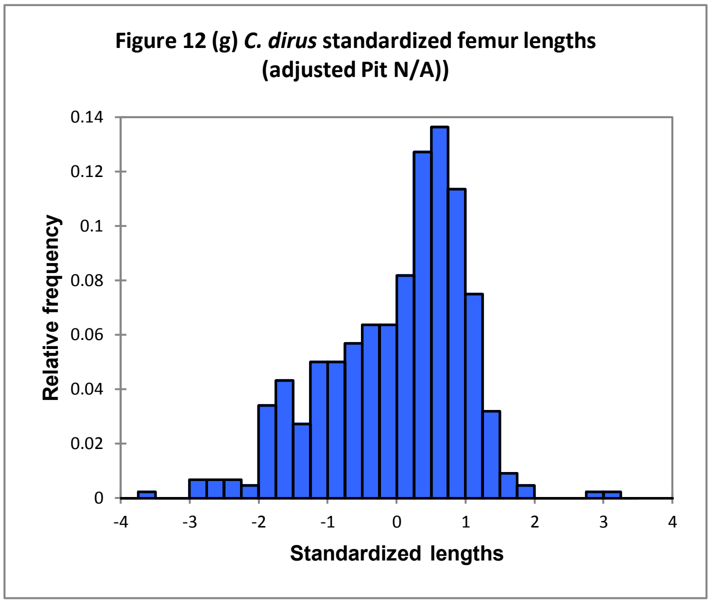


Figure 12 (g) *C. dirus* standardized femur lengths (adjusted Pit N/A))

Figure 12 (continued)

RESULTS

For an accurate statistical analysis in all of the cases that follow, let $f_{CLDQ}(x) = CLDQ$ and $f_{LBTP}(x) = LBTP$ for each pit that is being discussed, with $\alpha = 0.05$. Let

$$H_0\colon\ f_{CLDQ}(x) = f_{LBTP}(x) \qquad -\infty \leq x \leq \infty$$

$$H_1\colon\ f_{CLDQ}(x) \neq f_{LBTP}(x) \qquad -\infty \leq x \leq \infty.$$

In the event that two distributions are being compared, as in this case, a two-sample Kolmogorov-Smirnov test is used. In this way, each portion of the quarries being discussed can be examined without redefining the equation parameters for each individual case. In order to fail to reject the null hypothesis, the test statistic D must be greater than the negative of the critical two-tail value and less than the critical two-tail value, which also means that the p-value corresponding to D must be larger than $\propto$ in order to fail to reject the null hypothesis, or

$$-Critical\ value < \ D < -Critical\ two\ tail,$$

and

$$p - value < \propto.$$

In order for this to be done, all tested values had to be standardized. That includes the femur lengths, circumferences, and ratios of the original measurements; the Allosaur measurements adapted from Madsen (1976); and the adjusted dire wolf lengths due to missing epiphysis.

Case 1

Initially, the actual measured lengths of *A. fragilis* femora were compared to the measured lengths of *C. dirus* as shown in Figure 5 and Table 2,and Figure 7(a) and Table 4 respectively. Figure 13 shows the comparison of these distributions. In this case

$$D = 0.282,$$

$$p - value = 0.006,$$

and

$$\propto = 0.05.$$

So, since

$$0.006 < 0.05,$$

we reject the null hypothesis. Thus, the observed difference between the two distributions implies that the femur lengths of *A. fragilis* from the CLDQ differs significantly from the femur lengths of *C. dirus* from LBTP, implying that they do not have the same distribution of sizes.

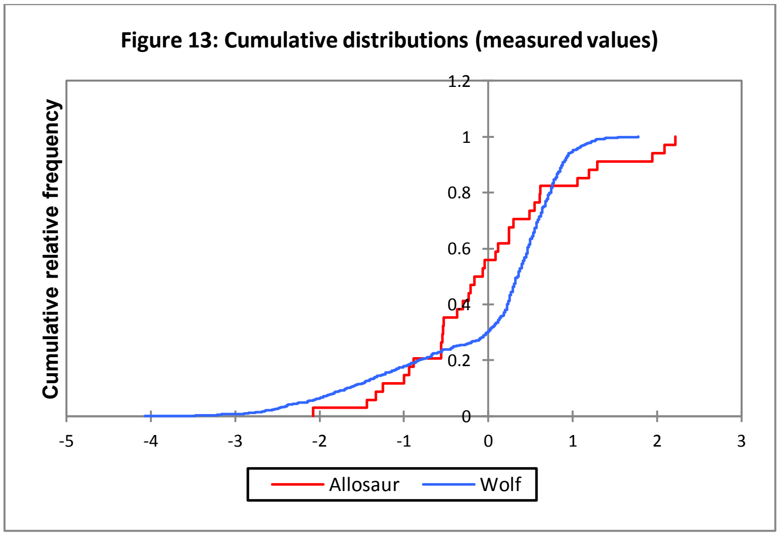


Figure 13: Comparison of the measured femur length distributions of *A. fragilis* and *C. dirus.*

Case 2

It cannot be forgotten that there were also an additional 31 *Allosaurus fragilis* bones measured from the CLDQ compiled by Madsen in 1976. Unfortunately, as they were recorded using an older numbering scheme no longer used, there is no easy way to verify which are the same bones and which are different from those measured for this study. Hence the previous case only uses those bones physically measured by the author; however, none of the recorded lengths or circumferences compiled by Madsen were consistent with the new measurements. Figure 6 shows all 65 measured *Allosaurus fragilis* femur lengths in one graph, making the assumption that no measurements are repeated.

When just measuring the length of the 31 *Allosaurus* femora available to Madsen and placing them in this distribution, the graph has a distinct L-shape to it, representing a living population that experienced some catastrophic event (Madsen 1976; Hunt 1986). It can be seen by comparing Figure 5 and Figure 6 that the original length measurements were relatively similar to the more recent measurements, and the shape of the graph is only slightly altered. However, this alteration is enough to change the curve from L-shaped previously observed to a slight U-shape. This is not entirely conclusive, though, as there are most likely repeated measurements as well as additional femurs to be found at the CLDQ, which could easily change the graph's shape in years to come. It can also be noted that whether actual measurements or adjusted measurement, the LBTP quarry never has a U-shaped distribution.

Secondarily, all of the measured values for *C. dirus* were compared to the measured values compiled by this study and those values from Madsen (1976). This new distribution is shown in Figure 6, adding an additional 31 bones to the original count. Figure 14 shows the comparison of these new distributions, and for this scenario,

$$D = 0.312,$$

$$p - value =< 0.0001,$$

and

$$\propto = 0.05.$$

So, since

$$p - value < \propto,$$

we reject the null hypothesis. It follows that the observed difference between the two distributions implies that the femur lengths of *A. fragilis* from the CLDQ differ significantly from the femur lengths of *C. dirus* from LBTP, implying that they do not have the same distribution of sizes.

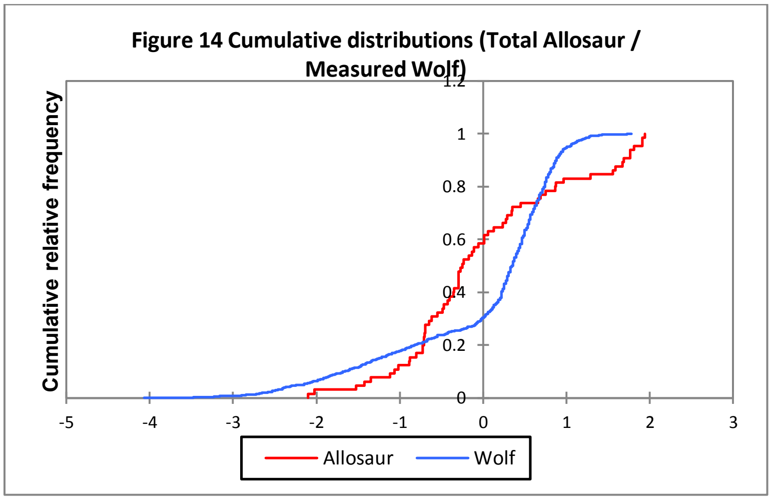


Figure 14: Comparison of the total *A. fragilis* and measured *C. dirus* femur lengths.

Case 3

The two populations were compared a third time after the measurements were adjusted to account for those bones missing their epiphyses. Those values can be seen in Table 4 and Figure 7(b). The cumulative distributions can be seen in Figure 15, in which

$$D = 0.286,$$

$$p - value \leq 0.0001,$$

and

$$\propto = 0.05.$$

So, since

$$p - value < \propto,$$

we can once again reject the null hypothesis. Therefore, the observed difference between the two distributions implies that the total femur lengths of *A. fragilis* from the CLDQ differ significantly from the adjusted femur ratios of *C. dirus* from LBTP. So these two populations once again appear to be noticeably different from one another.

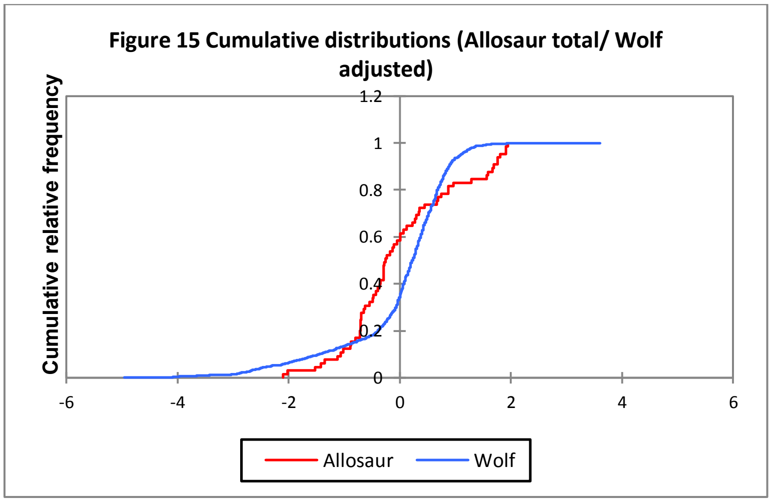


Figure 15: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths.

Case 4

Lastly, the femur lengths of *C. dirus* from each individual pit were compared to the total femur lengths of *A. fragilis* with the same assumptions and variables as the previous tests.

Pit 3

The distribution for Pit 3 can be seen in Table 5(a) and Figure 8(a) for the original values and Table 9(a) and Figure 12 (a) for the standardized values. The cumulative distributions can be seen in Figure 16, in which

$$D = 0.166,$$

$$p - value = 0.105,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \nless \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 3. So, these two populations appear to represent similar distributions.

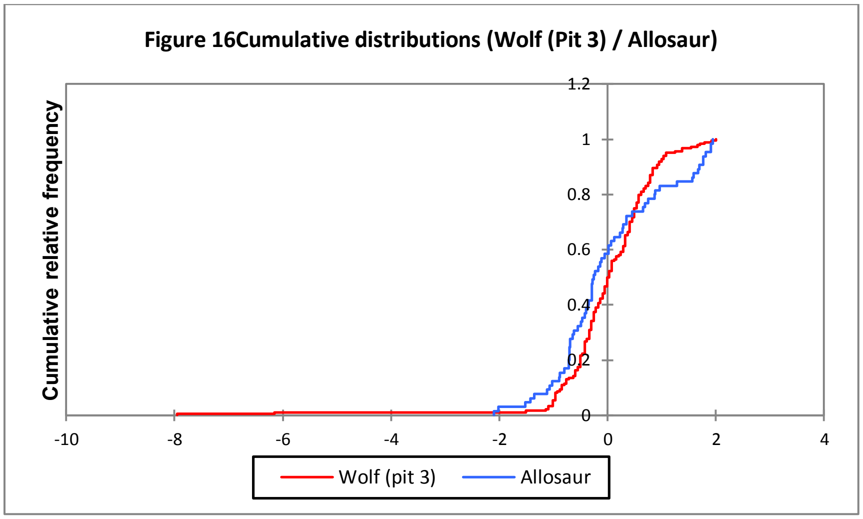


Figure 16: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 3.

Pit 4

The distribution for Pit 4 can be seen in Table 5(b) and Figure 8(b) for the original values and Table 9(b) and Figure 12 (b) for the standardized values. The cumulative distributions can be seen in Figure 17, in which

$$D = 0.134,$$

$$p - value = 0.366,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \nless \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 4. So, these two populations appear to represent similar distributions.

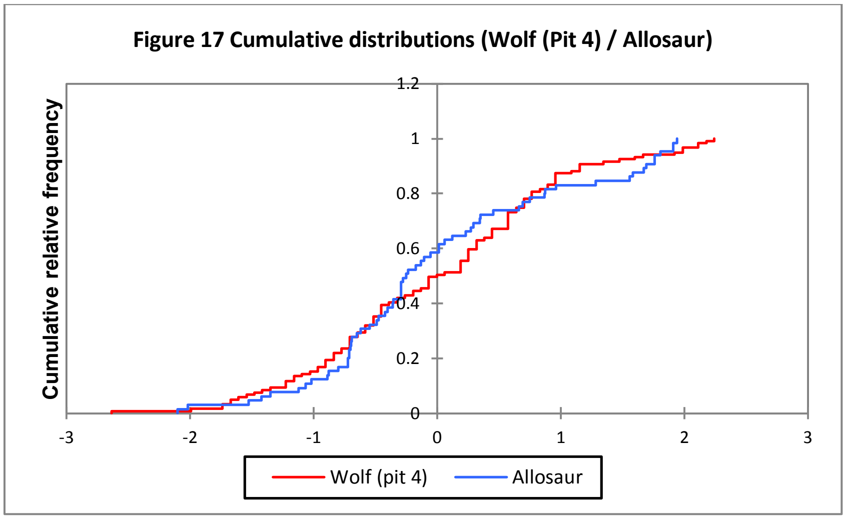


Figure 17: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 4.

Pit 13

The distribution for Pit 13 can be seen in Table 5(c) and Figure 8(c) for the original values and Table 9(c) and Figure 12 (c) for the standardized values. The cumulative distributions can be seen in Figure 18, in which

$$D = 0.094,$$

$$p - value = 0.896,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \nless \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 13. So, these two populations appear to represent similar distributions.

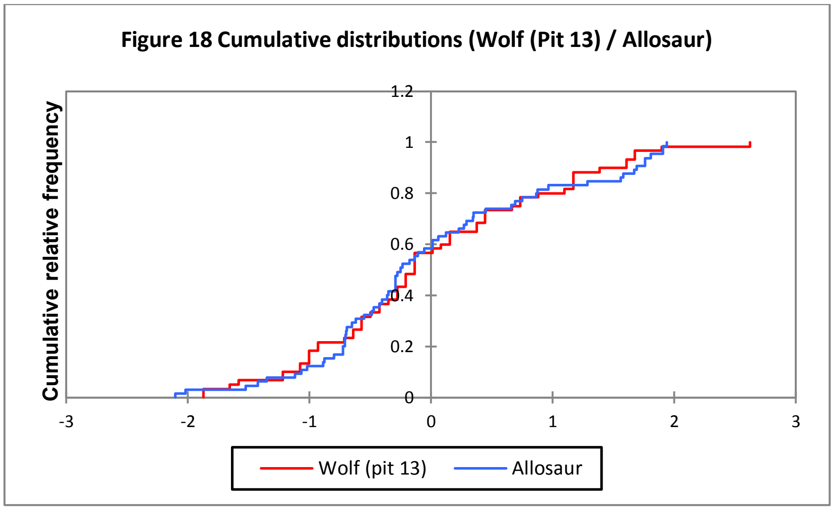


Figure 18: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 13.

Pit 61

The distribution for Pit 61 can be seen in Table 5(d) and Figure 8(d) for the original values and Table 9(d) and Figure 12 (d) for the standardized values. The cumulative distributions can be seen in Figure 19, in which

$$D = 0.113,$$

$$p - value = 0.633,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \not< \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 61. So, these two populations appear to represent similar distributions.

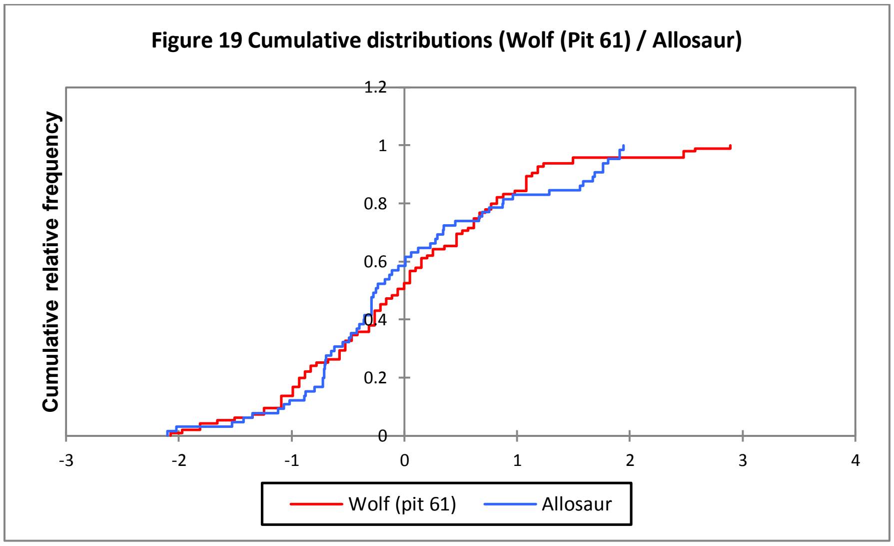


Figure 19: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 61.

Pits 60, 16, 90, and 91

As each of these pits have less than 10 femurs from each location, it was ineffective to use the Kolmogorov-Smirnov test on such a small sample size.

Pit 67

The distribution for Pit 67 can be seen in Table 5(e) and Figure 8(g) for the original values and Table 9(e) and Figure 12 (e) for the standardized values. The cumulative distributions can be seen in Figure 20, in which

$$D = 0.128,$$

$$p - value = 0.465,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \nless \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 67. So, these two populations appear to represent similar distributions.

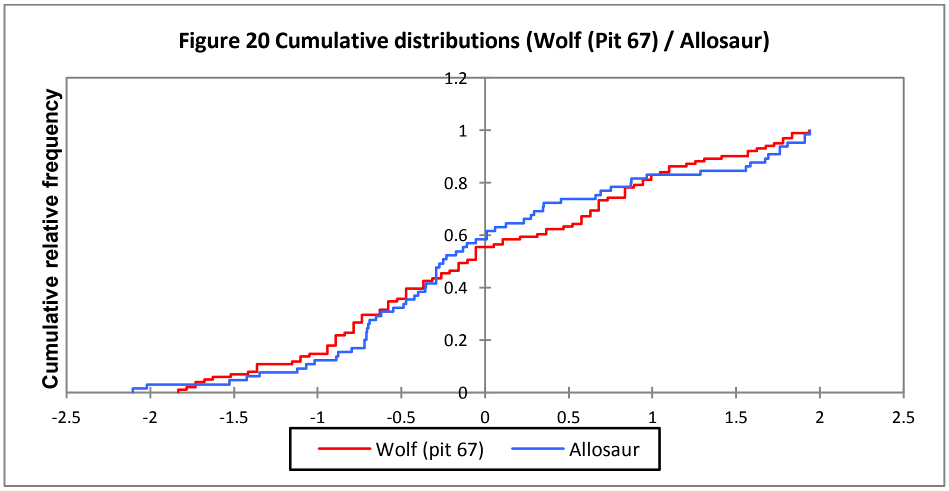


Figure 20: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 67.

Pit 77

The distribution for Pit 77 can be seen in Table 5(f) and Figure 8(h) for the original values and Table 9(f) and Figure 12 (f) for the standardized values. The cumulative distributions can be seen in Figure 21, in which

$$D = 0.254,$$

$$p - value = 0.116,$$

and

$$\propto = 0.05.$$

So, since

$$p - value \nless \propto,$$

we fail to reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ does not differ significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit 77. So, these two populations appear to represent similar distributions.

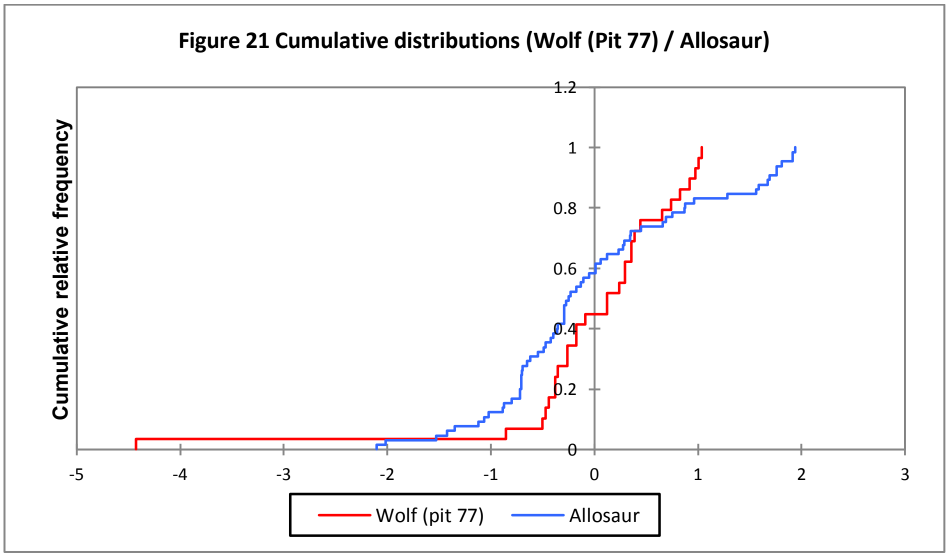


Figure 21: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit 77.

Pit N/A

The distribution for Pit N/A can be seen in Table 5(g) and Figure 8(i) for the original values and Table 9(g) and Figure 12 (g) for the standardized values. The cumulative distributions can be seen in Figure 22, in which

$$D = 0.194,$$

$$p - value = 0.022,$$

and

$$\propto = 0.05.$$

So, since

$$p - value < \propto,$$

we reject the null hypothesis. Therefore, the observed distribution of total femur lengths of *A. fragilis* from the CLDQ differs significantly from the adjusted femur lengths of *C. dirus* from LBTP Pit N/A. So, these two populations appear to represent distinctly different populations.

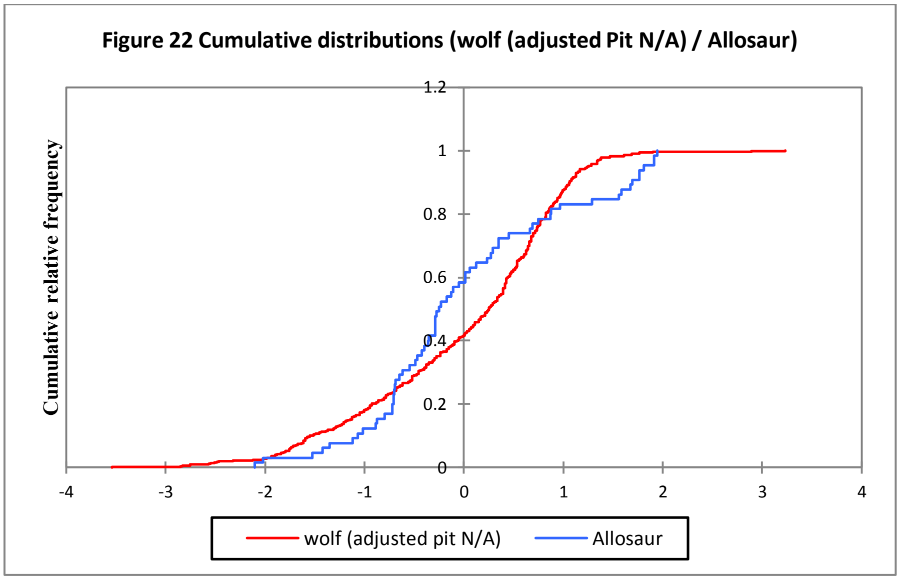


Figure 22: Comparison of the total *A. fragilis* and the adjusted *C. dirus* femur lengths from Pit N/A.

Case 5: Proportions

For the most generalized analysis of this study, the population proportions are compared at a 95% confidence interval, so let p_1 =the proportion of dire wolves that were juveniles, and let p_2 =the proportion of Allosaurs that were juveniles; then

$$H_0\colon\ p_1 - p_2 = 0$$

$$H_1\colon\ p_1 - p_2 > 0.$$

It is thought that hindlimb proportions for adult Allosaurs were reached when the femur was about 43cm long (Foster and Chure 2006). This means that of the bones measured for this study, 7 of 34 (20.6%) are thought to belong to juveniles and $p_2 = 0.2058$. At the La Brea Tar Pits, of the 1,045 dire wolf femurs measured, 332 (31.8%) had not experienced fusion of either one or both epiphyses, marking them as most likely belonging to juveniles, making $p_2 = 0.3183$. This gives us a $t\ stat = 3.7646$ and a $p - value = 0.0002$. As $0.0002 \ngtr 0.05$, we reject the null hypothesis, concluding that there is a significantly higher number of juveniles present at the LBTP than at the CLDQ.

When Madsen's additional 31 measurements are included, our proportion changes to 8 out of 65 (12.3%), resulting in an even more significant difference than before: $t\ stat = 4.9057$ and $p - value = 0.0001$. So, we once again reject the null hypothesis and conclude that the proportion of juveniles at the La Brea Tar Pits is significantly higher than the proportion of juveniles at the Cleveland-Lloyd Dinosaur Quarry.

However, if we were to take into account that Madsen considered a femur length of 56.0cm to be the upper boundary of subadult Allosaurs (Gates 2005), we can redo this equation in a different way. Still comparing the population proportions at a 95% confidence interval, let p_1 =the proportion of Allosaurs that were juveniles, and let p_2 =the proportion of dire wolves that were juveniles; then

$$H_0\colon\ p_1 - p_2 = 0$$

$$H_1:\ p_1 - p_2 > 0$$

Here we have 19 out of 34 (55.9%) considered to be juveniles, meaning $p_1 = 0.5588$ and then $P_2 = 0.3183$. In this case, the t stat=3.8614 and the p-value=0.0001. Since, 0.0001≯0.05, we reject the null hypothesis, as there is a significantly higher proportion of juveniles present at the CLDQ than at the LBTP.

Finally, using the same setup as the previous equation, and including Madsen's femur measurements as well, there are then 35 out of 65 (53.8%), gaining a similar conclusion as before: $t\ stat = 5.1848$ and $p - value = 0.0001$. Thus we reject the null hypothesis and can see that there is a significantly lower proportion of juveniles at the La Brea Tar Pits than at the Cleveland-Lloyd Dinosaur Quarry. It is important to note that these solutions are based on the assumption that individual dire wolf bones without fusion represent juveniles, not based on a specific size like the Allosaur bones. But either way, the proportions of juveniles in each location are significantly different from one another, only varying based on which quarry is thought to have the higher proportion.

CONCLUSIONS

The idea that the Cleveland-Lloyd Dinosaur Quarry is a predator trap has been the most dominant hypothesis for the quarry's fossil accumulation since 1980 (Gates 2005). As an alternative to this idea, Hunt (1986) proposed a massive flooding event, but in his paper he never actually ruled out the original hypothesis of it being a predator trap that ended in a flood; instead, he cited evidence in support of both ideas (1986). Over the years, there have been minimal additions made to the evidence supporting the predator trap hypothesis, but at the same time there has been no real evidence to refute it either.

As there are no known modern analogues to this type of situation, it is difficult to find a suitable example with which to compare the CLDQ. However, La Brea Tar Pits, with its overwhelming mass of predators, mostly comprised of *Canis dirus,* is a good start to the examination. While it may be hard to comprehend how a population of large reptiles could be accurately compared to a population of substantially smaller mammals, based on this analysis and as a basis for my hypothesis, during their respective time periods they seem to have been possibly leading surprisingly similar lives. Unfortunately, despite the supporting evidence, there are some obvious restrictions to this study such as the limited set of Allosaur fossils, the innate differences in bipedal versus quadrupedal animals, and the very obvious differences between reptiles and mammals.

However, it has been found that dinosaurs (especially theropods) are more closely related to modern birds than they are to modern reptiles and were more likely to be homeothermic than exothermic. Many different types of theropods, such as some species of Tyrannosaurs and *Deinonychus* are thought to have been pack hunters, not to mention the social behaviors of modern birds and crocodilians, which makes it reasonable to conclude that Allosaurs were also likely to have experienced this behavior as well (Ostrom 1986). In this case, both dire wolves and Allosaurs would be large, pack hunting animals, supporting and caring for their families by hunting herbivores large enough to feed every member. So it is reasonable to suppose that the two would have similar population distributions if both were caught in predator traps.

Although it is almost certain that the LBTP bone beds were assembled over a significant time period for each individual pit, the compiled data of the CLDQ seems to have a somewhat U-shaped curve indicating that the assemblage may have been amassed in one or two catastrophic events. However, this is both unlikely and not conclusive, as previously mentioned. So as an alternative idea, the data may actually be representing a seasonal accumulation without a distinct L- or U-shaped distribution, but this also is impossible to prove at this time.

Also when considering the climate of the Late Jurassic, especially in the area making up the Morrison Formation, which is considered to be semi-arid, it is reasonable to assume that droughts occurred periodically throughout the region (Demko and Parrish 1998). If the quarry is assumed to be an ephemeral pond, it does help to explain why so many animals may have been gathered in this single area. If water sources are scarce and frequently disappearing, it is reasonable to expect animals to gather around the longest lasting pond for as much time as they can.

In this high-stress environment, many animals competing for the same limited resources would lead to increased pressure and competition, which in turn would leave the young, old, or weakened dinosaurs far more susceptible to death than their mid-aged and stronger counterparts. The single egg found in the area with a secondary layer of shell supports this idea as in modern animals the excessive precipitation of a second shell only happens in high-stress environments (Hirsch et al. 1989). During times of extended drought, juveniles especially are susceptible to weakness and death, as they are not able to tolerate the increased demands of their environment (Hanks 1979, Conybeare and Haynes 1984, Haynes 1991). This idea is consistent with the higher number of juveniles present at the site (Gates 2005).

While drought has been known to be a contributing factor to the creation of a bone bed, dehydration is seldom the cause of death (Haynes 1991). More often than not, there is increased competition for food sources, leading to increased cases of malnutrition, various diseases, higher levels of aggression, and predation (Carpenter 1987, Haynes 1991). In this situation it is reasonable to think that there were many rotting carcasses and feces around the pool, which would facilitate the growth of a disease such as botulism that could spread through the carnivore population and quickly reduce their numbers without any evidence left in the fossil record (Sugiyama 1986). There is also the chance, though very rare in modern deposits, for miring of weakened individuals around the edge of the pond (Haynes 1991, Gates 2005). As there is no real evidence for miring in this quarry, this is included as an unsupported possibility.

Generally, due to the increased competition for vegetation around a water source during a drought, herbivores are the most susceptible to death during this time (Haynes 1991). This initially appears to be contradictory as the Cleveland-Lloyd Quarry has an abundance of carnivores, but when compared to the Ghost Ranch Coelophysis Quarry of the Late Triassic, which is also thought to be a result of drought (Schwartz and Gillette 1994), it is entirely plausible that something similar could happen to Allosaurs. They were the most common large-bodied carnivore of the time, and a large group of them could easily persuade any approaching herbivores to steer clear of the area, leaving us a population largely biased towards predators (Gates 2005). Also, the Allosaurs may have been initially attracted by large, weakened herbivores in the area, which would explain why most of the herbivores' bones are found at the quarry's base, with the Allosaur bones dominating the middle of the deposit (Gates 2005). While the initial situations are similar, there is no evidence for rapid burial in the CLDQ as there was in Ghost Ranch, making the tar pits a better comparison to this quarry as a predator trap. It is also reasonable to conclude that multiple events led to the burial and preservation of specimens, since there are large bones concentrated at the top and bottom of the quarry layer (Gates 2005). As the bed is relatively thin, most likely the bone bed formed over a fairly short amount of time (probably decades as opposed to centuries or millennia; Rogers 1993; Gates 2005). The most recent study conducted by Peterson et al. (2017) uses a close look at the sediment geochemistry and intramatrix bone fragment abrasion patterns to lend credence to the idea that the quarry was an ephemeral pond that experienced seasonal wet and dry cycles. This also supports thoughts that the bones present were accumulated over multiple depositional events (Peterson et al. 2017).

The statistics included in this paper show that despite the previous assumptions that the CLDQ was a predator trap, due mostly to its disproportionally large abundance of carnivorous dinosaurs, when compared to the quintessential predator trap that is the La Brea Tar Pits, that hypothesis is harder to support. The population distributions of the tar pits and the dinosaur quarry are distinctly different from one another in most considerations. Every iteration of the femur length distribution, whether compiled by this author, an earlier study, the actual measured values, or values adjusted to correct for missing pieces or broken bones, has produced an analysis concluding that the two localities are different. However, when the LBTP is separated into individual pits, all but one comparison concludes that the two locations have the same distribution. When this happens it is called a Simpson's Paradox (Wagner 1982), meaning that there is a confounding variable that is affecting the data that has not been taken into account yet. To make this study more conclusive, it might be beneficial to measure the length and circumference of the *C. dirus* humeri as well. With this data, a new calculation can be made producing the rough estimated weights of *C. dirus* found in the pits, which can then be compared to the *A. fragilis* weights that can already be calculated, which may produce a more accurate comparison of the sites. This may also fix the paradox that is present with the data as it stands now.

At this point the most likely scenario to explain the odd assemblage of bones at the CLDQ is a series of small to large flooding events that moved the bones of deceased animals from their original death site downstream to the quarry site. It would make sense for the area to be experiencing a drought as defended by Gates (2005), but it is also likely that there was another reason these animals were congregating in this area to begin with. It has been shown that both the prey of modern wolves and the prey of ancient Allosaurs were prone to migrations to maintain good food supply all year around. As a result, it is likely that *A. fragilis* also maintained a home territory and yearly nesting grounds like birds, wolves, and crocodilians do.

If there was an area near the CLDQ with a normally maintained water source, it would be a comfortable site for pack congregation and even a possible location for a nesting ground. While only one egg has thus far been found, there is no reason to think that no others have been discarded or will be found in the future. Thus, it is likely that migrating animals moved through the area on a regular basis with only a few perishing periodically, while the larger proportion of *A. fragilis* remaining near the area would produce more deceased specimens of that species to be preserved in the CLDQ. This along with the statistical analysis shown in this paper lends evidence to support the idea that, although the CLDQ has a large concentration of predatory dinosaurs, it is hard to say for certain that it is in fact a predator trap. There are far too many unaccounted for details to support a decisive conclusion at this time. However, as more excavations will undoubtedly produce new bones, work is needed, especially on the Cleveland-Lloyd quarry, to better understand the population distributions within the site in relation to other locations. That being said, as more fossils are uncovered, a more thorough examination of all the animals present can be made that should produce a more accurate comparison that is more all-encompassing than this study. Currently we are just beginning to understand what we do not know about the fossil record, while there are still many things that have not even been imagined that have yet to be found, not knowing just means that there is more to learn in the future.

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APPENDIX A

A. FRAGILIS FEMUR STATISTICS

Table 10

Allosaurus fragilis femur statistics (cm)

Specimen # UMNHVP	Circumference at midshaft (cm)	Length (cm)	(circumference/length)*100		Notes
9480	100.00	345	28.9855	L	
9480	106.00	357.6	29.6420	*	
6317	71.00	231	30.7359	R	
7894	123.00	396	31.0606	L	
7149	103.80	328	31.6463	R	
7886	169.00	517	32.6885	L	
10400+7906	165.00	492	33.5365	R	
C-1	157.80	468	33.7179	L	
7842	173.00	513	33.7231	L	
7895	138.50	405	34.1975	L	
C-25	194.00	562	34.5195	R	
C-3	197.00	566	34.8056	L	
7900	163.00	466	34.9785	L	
7910	176.00	502	35.0597	R	
7909	185.50	524	35.4007	R	
7907	164.00	463	35.4211	R	
7885	213.60	594.3	35.9414	*	
7897	169.00	467	36.1884	L	
7911	234.00	642	36.4485	R	
7908	171.00	463	36.9330	R	
12231	201.30	541.9	37.1470	*	
C-29	324.00	868	37.3271	L	

(Continued on next page)

Table 10 (continued)

7904	154.50	413	37.4092	R	
7905	221.00	586	37.7133	R	
20363	336.00	887.6	37.8548	*	
12268	205.00	538	38.1040	L	
7889	322.50	846	38.1205	L	
7890	272.50	710	38.3802	L	
C-26	227.50	586	38.8225	L	
7883	248.20	633	39.2101	L	
C-27	245.00	623	39.3258	L	
7884	255.00	643	39.6578	L	
7882	299.10	746	40.0938	*	
C-30	294.00	731	40.2188	L	

All numbers with a C, are casts of bones found in the CLDQ quarry that have been cut or otherwise altered by scientific examination.

Those bones with * in place of a right or left indication, were measured by C-T scan provided by Peter Bishop.

Table 11

A. fragilis femur statistics modified from Madsen 1976

Specimen # UUVP	circumference at midshaft (cm)	length (cm)	C:Lx100		Notes
6023	7.40	24.50	30.2040	R	
2559	13.80	43.50	31.7241	L	
847	14.20	45.00	31.5555	L	
30-35	14.70	46.50	31.6129	L	
30-375	15.50	46.50	33.3333	R	
3164	14.70	47.50	30.9473	R	
492	16.20	48.00	33.7500	L	
2280	16.80	50.50	33.2673	R	
30-724	16.50	52.50	31.4285	R	
718	17.90	53.50	33.4579	L	
30-16	17.90	53.50	33.4579	L	
30-743	17.50	53.50	32.7102	L	
40-268	17.40	53.50	32.5233	R	
3192	19.40	54.50	35.5963	L	
5991	18.40	55.50	33.1531	R	
1364	21.00	57.50	36.5217	L	
30-17	20.60	60.50	34.0495	R	
3980	21.00	63.00	33.3333	R	
3385	21.70	66.00	32.8787	L	
5302	25.50	69.50	36.6906	L	
Cast	25.50	70.00	36.4285	L	
Cast	27.60	73.00	37.8082	R	

(Continued on next page)

Table 11 (continued)

5993	29.00	80.00	36.2500	L	
6000	33.70	85.00	39.6470	L	
1165	29.50	86.50	34.1040	R	
6000	31.30	88.00	35.5681	R	
DNM No. C	32.60	88.00	37.0454	R	
3694	30.70	90.50	33.9226	L	
DNM No. D	34.80	90.50	38.4530	L	
DNM	33.50	91.00	36.8131	L	

These circumference and length measurements here were copied from Madsen (1976) then converted to centimenters to make them more consistent with the rest of the new measurements, and the C:Lx100 ratio was recalculated to attain a more accurate value.

APPENDIX B

C. DIRUS FEMUR STATISTICS

Table 12

C. dirus femur statistics (Pit 3)

Pit	Specimen #	Circumference at midshaft	Length	(circumference/length)*100		Notes
3	H-218	6.30	23.70	26.5822	R	
3	H-219	6.10	24.10	25.3112	R	
3	H-221	5.80	24.00	24.1666	R	
3	H-222	6.00	23.00	26.0869	R	
3	H-224	5.70	23.30	24.4635	R	
3	H-225	6.20	24.45	25.3578	R	
3	H-231	6.00	25.25	23.7623	R	
3	H-233	5.40	23.70	22.7848	R	
3	H-243	5.95	25.00	23.8000	R	
3	H-245	5.70	23.50	24.2553	R	
3	H-254	7.20	25.15	28.6282	L	
3	H-256	6.20	23.75	26.1052	R	
3	H-263	5.70	23.60	24.1525	R	
3	H-264	6.20	23.95	25.8872	R	
3	H-265	6.60	24.15	27.3291	R	
3	H-266	6.70	24.70	27.1255	R	
3	H-275	6.00	24.40	24.5901	R	
3	H-278	6.20	24.40	25.4098	R	
3	H-285	6.00	26.30	22.8136	R	
3	H-291	6.40	24.50	26.1224	R	
3	H-295	6.35	25.25	25.1485	R	
3	H-297	4.60	23.40	19.6581	R	

(Continued on next page)

Table 12 (continued)

3	H-298	6.10	24.70	24.6963	R	
3	H-302	5.60	22.85	24.5076	R	
3	H-303	5.80	23.80	24.3697	R	
3	H-304	5.80	22.80	25.4385	R	
3	H-305	6.20	24.95	24.8496	R	
3	H-307	6.10	24.10	25.3112	R	
3	H-308	6.15	24.30	25.3086	R	
3	H-309	6.00	24.75	24.2424	R	
3	H-311	6.70	22.80	29.3859	R	
3	H-316	5.90	24.35	24.2299	R	
3	H-323	6.30	24.65	25.5578	R	
3	H-325	6.20	23.70	26.1603	R	
3	H-330	6.25	23.40	26.7094	R	
3	H-332	5.65	24.65	22.9208	R	
3	H-334	5.95	22.80	26.0964	R	
3	H-336	6.95	26.00	26.7307	R	
3	H-339	6.30	24.70	25.5060	R	
3	H-341	5.60	23.65	23.6786	R	
3	H-342	6.40	24.55	26.0692	R	
3	H-343	5.90	23.65	24.9471	R	
3	H-347	6.50	25.65	25.3411	R	
3	H-348	6.60	25.30	26.0869	R	
3	H-349	5.80	23.60	24.5762	R	
3	H-350	5.80	23.40	24.7863	R	
3	H-355	5.90	24.05	24.5322	R	
3	H-359	6.60	23.25	28.3870	R	

(Continued on next page)

Table 12 (continued)

3	H-360	6.40	23.60	27.1186	R	
3	H-368	6.30	23.50	26.8085	R	
3	H-370	6.10	24.95	24.4488	R	
3	H-370	5.80	23.50	24.6808	R	
3	H-371	6.15	24.50	25.1020	R	
3	H-374	5.90	24.50	24.0816	R	
3	H-377	6.00	24.35	24.6406	R	
3	H-379	5.65	24.40	23.1557	R	
3	H-385	6.05	23.85	25.3668	R	
3	H-386	6.10	24.35	25.0513	R	
3	H-389	6.00	23.90	25.1046	R	
3	H-390	6.15	23.95	25.6784	R	
3	H-391	6.15	23.50	26.1702	R	
3	H-395	6.00	24.30	24.6913	R	
3	H-400	5.90	23.40	25.2136	R	
3	H-416	5.95	24.40	24.3852	R	
3	H-417	6.00	24.40	24.5901	R	
3	H-418	6.10	24.50	24.8979	R	
3	H-420	6.20	24.70	25.1012	R	
3	H-425	5.55	23.50	23.6170	R	
3	H-428	5.35	23.05	23.2104	R	
3	H-430	6.05	23.30	25.9656	R	
3	H-435	5.70	23.40	24.3589	R	
3	H-436/H-456	6.00	24.85	24.1448	R	
3	H-443	5.30	23.30	22.7467	R	
3	H-456	6.00	24.10	24.8962	R	

(Continued on next page)

Table 12 (continued)

3	H-459	5.85	23.00	25.4347	R	
3	H-462	6.60	23.90	27.6150	R	
3	H-469	6.20	23.00	26.9565	R	
3	H-476	5.85	24.00	24.3750	R	
3	H-482	6.50	26.05	24.9520	R	
3	H-483	6.60	24.65	26.7748	R	
3	H-484	6.30	24.95	25.2505	R	
3	H-486	5.50	23.35	23.5546	R	
3	H-487	6.70	25.50	26.2745	R	
3	H-492	5.85	24.00	24.3750	R	
3	H-514	6.55	25.30	25.8893	R	
3	H-515	5.90	23.70	24.8945	R	
3	H-518	6.05	23.85	25.3668	R	
3	H-519	6.20	24.60	25.2032	R	
3	H-520	6.50	24.10	26.9709	R	
3	H-521	6.10	22.20	27.4774	R	
3	H-523	5.80	22.85	25.3829	R	
3	H-524	5.90	23.80	24.7899	R	
3	H-525	5.70	24.25	23.5051	R	bite? Picture #3
3	H-526	6.15	24.95	24.6492	R	
3	H-527	6.10	25.10	24.3027	R	
3	H-528	5.70	23.45	24.3070	R	
3	H-529	6.00	24.55	24.4399	R	
3	H-530	5.90	23.15	25.4859	R	
3	H-531	6.30	23.80	26.4705	R	
3	H-532	5.50	22.95	23.9651	R	

(Continued on net page)

Table 12 (continued)

3	H-533	5.75	23.50	24.4680	R	
3	H-534	5.70	23.70	24.0506	R	
3	H-545	6.40	25.10	25.4980	R	
3	H-554	5.85	22.80	25.6578	R	
3	H-560	6.70	25.00	26.8000	L	
3	H-577	5.75	23.40	24.5726	L	
3	H-599	5.85	23.40	25.0000	R	
3	H-600	6.90	23.70	29.1139	L	broken?/weird growth midshaft
3	H-608	6.10	23.60	25.8474	L	
3	H-613	5.90	23.35	25.2676	L	Incomplete
3	H-630	5.95	23.60	25.2118	L	
3	H-638	5.90	23.90	24.6861	L	
3	H-641	6.30	25.00	25.2000	L	
3	H-645	6.00	24.80	24.1935	L	
3	H-647	6.40	24.60	26.0162	L	
3	H-650	6.10	24.35	25.0513	L	
3	H-654	6.20	23.75	26.1052	L	
3	H-657	6.60	26.15	25.2390	L	
3	H-662	6.20	25.20	24.6031	L	
3	H-667	6.30	24.70	25.5060	L	
3	H-668	6.10	23.95	25.4697	L	
3	H-670	6.70	24.10	27.8008	L	
3	H-671	6.45	25.15	25.6461	L	
3	H-672	5.70	22.90	24.8908	L	
3	H-678	6.80	24.45	27.8118	L	
3	H-682	6.30	24.60	25.6097	L	

(Continued on next page)

Table 12 (continued)

3	H-689	6.00	22.70	26.4317	L	
3	H-693	6.10	23.30	26.1802	L	
3	H-695	6.50	24.20	26.8595	L	bite?
3	H-696	6.70	25.85	25.9187	L	
3	H-698	6.00	23.10	25.9740	L	
3	H-712	6.10	23.65	25.7928	L	
3	H-724	6.05	23.95	25.2609	L	
3	H-733	6.20	22.70	27.3127	L	
3	H-734	5.20	22.85	22.7571	L	
3	H-736	5.95	24.05	24.7401	L	Incomplete
3	H-750	6.05	24.40	24.7950	L	
3	H-753	5.75	23.60	24.3644	L	Incomplete
3	H-768	5.70	24.80	22.9838	L	Incomplete
3	H-780	6.45	24.20	26.6528	L	
3	H-787	6.10	24.00	25.4166	L	Incomplete
3	H-788	6.10	25.20	24.2063	L	
3	H-789	6.35	23.55	26.9639	L	
3	H-791	5.65	24.10	23.4439	L	
3	H-797	6.40	26.40	24.2424	L	bite?
3	H-799	5.80	23.40	24.7863	L	Incomplete
3	H-801	5.70	24.50	23.2653	L	
3	H-802	6.10	24.55	24.8472	L	Incomplete
3	H-804	6.00	23.50	25.5319	L	
3	H-805	6.55	25.65	25.5360	L	
3	H-808	6.40	24.95	25.6513	L	
3	H-809	5.75	24.85	23.1388	L	

(Continued on next page)

Table 12 (continued)

3	H-810	6.00	24.75	24.2424	L	
3	H-811	6.60	23.75	27.7894	L	
3	H-819	6.05	23.50	25.7446	L	
3	H-822	6.00	23.10	25.9740	L	
3	H-824	6.40	23.95	26.7223	L	
3	H-826	6.08	24.00	25.3333	L	
3	H-827	5.60	24.05	23.2848	L	
3	H-830	5.45	22.85	23.8512	L	
3	H-834	6.50	24.60	26.4227	L	
3	H-836	5.90	23.10	25.5411	L	
3	H-838	6.20	25.00	24.8000	L	Incomplete
3	H-841	6.40	25.00	25.6000	L	gnawed on?
3	H-849	5.70	23.85	23.8993	L	
3	H-859	6.00	24.60	24.3902	L	
3	H-864	6.10	23.55	25.9023	L	Incomplete
3	H-868	6.35	24.90	25.5020	L	
3	H-876	6.35	24.60	25.8130	L	
3	H-886	6.30	24.10	26.1410	L	healed wound?/incomplete
3	H-899	6.00	22.85	26.2582	L	
3	H-901	6.25	23.65	26.4270	L	
3	H-908	6.00	24.90	24.0963	L	
3	LACMHC-12758	6.10	24.50	24.8979	L	weathered/incomplete
3	LACMHC-12760	6.00	23.65	25.3699	L	weathered/incomplete
3	LACMHC-12767	5.70	22.65	25.1655	L	weathered/incomplete
3	LACMHC-12771	4.60	14.50	31.7241	L	weathered pic #4/incomplete
3	LACMHC-12776	6.50	24.05	27.0270	L	Incomplete

(Continued on next page)

Table 12 (continued)

3	LACMHC-12777	5.70	23.65	24.1014	L	
3	LACMHC-12797	5.90	24.40	24.1803	R	Chewed?
3	LACMHC-12830	5.15	16.65	30.9309	R	
3	LACMHC-16745	5.90	24.65	23.9350	R	
3	LACMHC-7405	6.00	24.50	24.4897	R	
3	LACMHC-7415	6.60	24.00	27.5000	R	

Table 13

C. dirus femur statistics (Pit 4)

Pit	Specimen #	Circumference at midshaft	Length	(circumference/length)*100		Notes
4	H-217	6.90	25.20	27.3809	R	
4	H-225	6.10	25.05	24.3512	R	
4	H-226	6.85	26.40	25.9469	R	
4	H-227	6.60	24.20	27.2727	R	
4	H-228	6.55	26.05	25.1439	L	
4	H-234	6.15	24.20	25.4132	R	
4	H-237	6.45	25.65	25.1461	R	
4	H-238	5.90	24.15	24.4306	R	
4	H-249	5.95	24.40	24.3852	R	
4	H-252	6.35	24.50	25.9183	R	
4	H-257	6.00	25.00	24.0000	R	
4	H-258	5.85	23.55	24.8407	R	
4	H-261	6.80	25.25	26.9306	R	
4	H-262	6.00	25.30	23.7154	R	
4	H-267	6.40	24.05	26.6112	R	
4	H-270	6.70	25.30	26.4822	R	
4	H-271	7.00	24.80	28.2258	R	
4	H-276	6.55	25.60	25.5859	R	
4	H-281	6.50	25.20	25.7936	R	
4	H-282	5.85	22.70	25.7709	R	
4	H-283	6.70	23.80	28.1512	R	
4	H-290	5.60	24.60	22.7642	R	
4	H-293	6.90	26.25	26.2857	R	

(Continued on next page)

Table 13 (continued)

4	H-300	6.15	23.65	26.0042	R	
4	H-306	6.30	25.50	24.7058	R	
4	H-314	6.40	25.45	25.1473	R	
4	H-321	6.10	24.70	24.6963	R	
4	H-324	5.95	23.70	25.1054	R	
4	H-327	5.70	24.20	23.5537	R	
4	H-328	5.90	24.00	24.5833	R	
4	H-335	6.30	23.40	26.9230	R	
4	H-344	5.90	24.30	24.2798	R	
4	H-352	6.50	24.50	26.5306	R	
4	H-354	6.25	24.30	25.7201	R	
4	H-358	6.55	26.50	24.7169	R	
4	H-364	5.90	23.90	24.6861	R	
4	H-375	5.95	24.95	23.8476	R	
4	H-382	6.20	24.05	25.7796	R	
4	H-383	6.30	24.35	25.8726	R	
4	H-392	6.30	26.45	23.8185	R	
4	H-401	6.50	26.30	24.7148	R	
4	H-414	6.60	25.90	25.4826	R	
4	H-415	6.10	24.40	25.0000	R	
4	H-424	6.60	24.90	26.5060	R	
4	H-429	6.35	24.70	25.7085	R	
4	H-432	6.20	25.50	24.3137	R	
4	H-439	6.85	25.10	27.2908	R	
4	H-448	6.20	25.10	24.7011	R	
4	H-451	5.40	23.20	23.2758	R	

(Continued on next page)

Table 13 (continued)

4	H-467	6.45	25.65	25.1461	R	
4	H-472	7.10	25.50	27.8431	R	
4	H-474	6.10	24.30	25.1028	R	
4	H-475	6.25	24.90	25.1004	R	
4	H-510	6.80	26.40	25.7575	R	
4	H-511	6.50	25.30	25.6916	R	
4	H-512	6.45	24.95	25.8517	R	
4	H-513	6.35	24.25	26.1855	R	
4	H-555	5.85	25.35	23.0769	R	
4	H-556	6.05	23.85	25.3668	R	
4	H-563	5.75	23.45	24.5202	L	
4	H-565	7.00	26.00	26.9230	L	
4	H-567	6.20	24.45	25.3578	L	
4	H-572	6.30	24.90	25.3012	L	
4	H-589	6.25	25.00	25.0000	L	
4	H-603	5.85	24.05	24.3243	L	
4	H-611	6.00	24.40	24.5901	L	bite marks?
4	H-614	6.30	25.65	24.5614	L	
4	H-619	6.85	24.90	27.5100	L	
4	H-636	6.50	24.75	26.2626	L	
4	H-643	6.50	25.35	25.6410	L	bite marks?
4	H-646	5.70	23.40	24.3589	L	
4	H-658	6.35	25.10	25.2988	L	
4	H-659	6.10	24.70	24.6963	L	
4	H-661	5.90	23.50	25.1063	L	
4	H-663	6.50	24.00	27.0833	L	

(Continued on next page)

Table 13 (continued)

4	H-664	6.45	25.10	25.6972	L	
4	H-674	5.80	25.35	22.8796	L	bite?
4	H-676	6.45	25.45	25.3438	L	
4	H-677	6.30	25.00	25.2000	L	
4	H-680	6.15	25.80	23.8372	L	
4	H-683	5.80	23.85	24.3186	L	
4	H-684	6.40	25.50	25.0980	L	bite/gnawed?
4	H-686	6.20	24.90	24.8995	L	
4	H-687	5.95	24.35	24.4353	L	
4	H-692	6.25	23.60	26.4830	L	
4	H-702	6.50	24.10	26.9709	L	bite marks?
4	H-714	6.10	24.95	24.4488	L	
4	H-717	5.60	24.40	22.9508	L	
4	H-721	6.20	24.15	25.6728	L	
4	H-725	6.00	24.40	24.5901	L	
4	H-727	6.30	24.20	26.0330	L	
4	H-732	6.30	25.20	25.0000	L	
4	H-739	6.00	23.45	25.5863	L	
4	H-749	5.95	24.70	24.0890	L	
4	H-756	5.60	23.80	23.5294	L	
4	H-760	6.40	24.25	26.3917	L	
4	H-764	6.10	24.20	25.2066	L	
4	H-765	6.45	24.95	25.8517	L	
4	H-767	6.20	25.20	24.6031	L	
4	H-770	6.35	25.25	25.1485	L	
4	H-774	6.10	25.20	24.2063	L	

(Continued on next page)

Table 13 (continued)

4	H-778	6.30	24.55	25.6619	L	
4	H-779	5.95	23.95	24.8434	L	
4	H-780	6.70	25.50	26.2745	L	
4	H-786	6.25	25.20	24.8015	L	
4	H-790	6.25	25.20	24.8015	L	
4	H-793	6.65	25.30	26.2845	L	
4	H-794	6.40	25.40	25.1968	L	
4	H-795	6.80	24.95	27.2545	L	
4	H-820	6.40	24.35	26.2833	L	
4	H-823	6.40	24.35	26.2833	L	
4	H-831	6.10	24.65	24.7464	L	
4	H-855	5.85	24.10	24.2738	L	
4	H-865	6.15	24.60	25.0000	L	
4	H-873	5.95	24.70	24.0890	L	
4	H-879	6.70	26.30	25.4752	L	
4	H-895	6.20	23.80	26.0504	L	
4	LACMHC-12801	6.25	25.00	25.0000	R	
4	LACMHC-12803	6.15	24.10	25.5186	R	

Table 14

C. dirus femur statistics (Pit 13)

Pit	Specimen #	Circumference at midshaft	Length	(circumference/length)*100		Notes
13	H-228	6.10	24.90	24.4979	R	beat up
13	H-230	5.85	24.60	23.7804	R	
13	H-251	6.40	23.60	27.1186	R	
13	H-272	5.90	23.30	25.3218	R	
13	H-292	5.55	22.95	24.1830	R	
13	H-310	6.10	23.70	25.7383	R	
13	H-317	6.85	24.95	27.4549	R	
13	H-331	6.15	23.70	25.9493	R	
13	H-351	5.80	24.90	23.2931	R	
13	H-353	5.75	22.65	25.3863	R	
13	H-413	5.95	22.50	26.4444	R	
13	H-423	5.70	23.60	24.1525	R	
13	H-444	6.20	23.65	26.2156	R	
13	H-450	5.70	23.05	24.7288	R	
13	H-453	6.30	24.95	25.2505	R	
13	H-463	6.05	23.15	26.1339	R	
13	H-464	5.90	23.70	24.8945	R	
13	H-470	6.25	24.25	25.7731	R	
13	H-471	5.75	23.35	24.6252	R	
13	H-477	6.40	24.05	26.6112	R	
13	H-479	6.80	24.40	27.8688	R	chewed?/beat up?
13	H-505	6.00	23.90	25.1046	R	
13	H-506	5.60	23.65	23.6786	R	

(Continued on next page)

Table 14 (continued)

13	H-507	6.00	24.60	24.3902	R	
13	H-508	6.35	24.10	26.3485	R	beat up
13	H-509	5.80	22.95	25.2723	R	
13	H-548	6.50	23.60	27.5423	R	
13	H-549	6.50	24.30	26.7489	R	
13	H-550	5.95	23.40	25.4273	R	
13	H-551	6.20	23.45	26.4392	R	
13	H-552	5.60	22.50	24.8888	R	
13	H-553	6.30	22.70	27.7533	R	
13	H-574	6.00	24.30	24.6913	L	
13	H-597	6.30	23.50	26.8085	L	bite?
13	H-626	5.80	23.90	24.2677	L	
13	H-632	5.90	24.05	24.5322	L	
13	H-673	6.05	24.75	24.4444	L	
13	H-701	6.05	23.80	25.4201	L	
13	H-704	6.10	25.10	24.3027	L	chewed?
13	H-705	5.90	23.10	25.5411	L	
13	H-710	6.10	23.50	25.9574	L	
13	H-718	6.15	24.10	25.5186	L	gnawed?
13	H-719	6.05	23.70	25.5274	L	
13	H-742	6.40	24.60	26.0162	L	
13	H-762	6.20	23.10	26.8398	L	
13	H-784	5.80	24.60	23.5772	R	
13	H-796	6.05	23.70	25.5274	R	
13	H-800	5.45	23.55	23.1422	L	
13	H-812	6.10	23.10	26.4069	L	

(Continued on next page)

Table 14 (continued)

13	H-829	6.50	23.05	28.1995	L	
13	H-848	5.90	24.55	24.0325	L	
13	H-858	5.75	23.35	24.6252	L	
13	H-869	5.60	23.40	23.9316	L	
13	H-881	6.25	23.85	26.2054	L	
13	H-883	5.70	23.90	23.8493	L	
13	H-890	6.20	23.15	26.7818	L	
13	H-896	5.90	25.60	23.0468	L	
13	H-909	6.25	23.40	26.7094	L	
13	LACMHC-12775	5.70	23.65	24.1014	L	chewed?
13	LACMHC-12819	6.05	24.10	25.1037	R	worn edge

Table 15

C. dirus femur statistics (Pit 9)

Pit	Specimen #	Circumference at midshaft	Length	(circumference/length)*100		Notes
9	H-223	6.10	22.25	27.4157	R	

Table 16

C. dirus femur statistics (Pit 61)

Pit	Specimen #	Circumference at midshaft	Length	(circumference/length)*100		Notes
61	H-232	6.70	24.90	26.9076	R	
61	H-241	6.40	25.15	25.4473	R	
61	H-242	5.85	25.05	23.3532	R	
61	H-244	6.60	24.80	26.6129	R	
61	H-250	6.60	25.10	26.2948	R	
61	H-259	6.00	24.40	24.5901	R	
61	H-260	5.70	23.80	23.9495	R	
61	H-268	5.85	24.80	23.5887	R	
61	H-274	6.25	24.95	25.0501	R	
61	H-289	6.00	23.30	25.7510	R	
61	H-319	6.45	24.35	26.4887	R	
61	H-329	6.50	25.40	25.5905	R	
61	H-337	6.80	25.80	26.3565	R	
61	H-357	6.25	24.30	25.7201	R	
61	H-361	5.80	23.85	24.3186	R	
61	H-367	6.30	24.10	26.1410	R	
61	H-384	6.10	23.40	26.0683	R	
61	H-421	6.30	24.05	26.1954	R	
61	H-422	6.10	23.80	25.6302	R	
61	H-449	6.20	23.40	26.4957	R	
61	H-455	6.10	23.55	25.9023	R	
61	H-457	6.95	25.30	27.4703	R	

(Continued on next page)

Table 16 (continued)

61	H-466	6.40	25.20	25.3968	R	
61	H-494	6.80	24.55	27.6985	R	
61	H-495	6.50	22.60	28.7610	R	
61	H-496	6.40	24.70	25.9109	R	
61	H-499	6.20	23.50	26.3829	R	
61	H-504	6.30	24.95	25.2505	R	
61	H-541	6.50	24.50	26.5306	R	
61	H-542	6.40	23.40	27.3504	R	
61	H-543	6.15	23.85	25.7861	R	
61	H-544	6.10	23.70	25.7383	R	
61	H-545	6.65	24.40	27.2540	R	
61	H-564	6.55	25.45	25.7367	L	
61	H-580	5.30	23.90	22.1757	L	
61	H-583	6.00	25.50	23.5294	L	
61	H-584	6.15	24.15	25.4658	L	
61	H-585	5.90	24.15	24.4306	L	
61	H-587	6.50	23.45	27.7185	L	
61	H-591	6.70	25.55	26.2230	L	
61	H-595	5.65	23.15	24.4060	L	
61	H-605	6.15	24.80	24.7983	L	
61	H-606	6.40	26.75	23.9252	L	
61	H-620	6.65	24.50	27.1428	L	
61	H-622	5.95	23.90	24.8953	L	
61	H-637	6.50	23.30	27.8969	L	
61	H-642	6.60	25.50	25.8823	L	
61	H-649	6.10	24.35	25.0513	L	

(Continued on next page)

Table 16 (continued)

61	H-652	6.40	25.40	25.1968	L	
61	H-656	6.20	24.60	25.2032	L	
61	H-681	6.30	23.30	27.0386	L	
61	H-685	5.75	24.20	23.7603	L	
61	H-688	5.80	23.50	24.6808	L	
61	H-703	6.35	23.05	27.5488	L	
61	H-711	6.10	24.80	24.5967	L	
61	H-720	5.75	22.35	25.7270	L	
61	H-726	5.90	23.15	25.4859	L	
61	H-728	6.30	24.10	26.1410	L	
61	H-730	6.25	23.80	26.2605	L	
61	H-735	5.90	24.30	24.2798	L	
61	H-746	6.50	24.60	26.4227	L	
61	H-747	5.65	24.10	23.4439	L	
61	H-748	6.00	25.15	23.8568	L	
61	H-751	6.10	24.85	24.5472	L	
61	H-752	6.10	22.45	27.1714	L	
61	H-757	6.40	23.45	27.2921	L	
61	H-759	7.00	26.75	26.1682	L	
61	H-769	6.05	25.40	23.8188	L	
61	H-771	6.10	25.40	24.0157	L	
61	H-777	6.00	24.05	24.9480	L	
61	H-815	6.00	24.40	24.5901	L	
61	H-817	6.00	24.45	24.5398	L	
61	H-840	6.50	25.00	26.0000	L	
61	H-845	6.35	25.00	25.4000	L	

(Continued on next page)

Table 16 (continued)

61	H-847	6.20	24.50	25.3061	L	
61	H-853	6.20	23.60	26.2711	L	
61	H-856	5.95	22.60	26.3274	L	
61	H-857	6.55	25.40	25.7874	L	
61	H-861	6.20	25.10	24.7011	L	
61	H-867	5.50	23.55	23.3545	L	
61	H-871	6.15	22.75	27.0329	L	
61	H-874	6.70	25.80	25.9689	L	
61	H-887	6.20	23.95	25.8872	L	
61	H-892	5.90	23.30	25.3218	L	
61	H-893	6.05	22.90	26.4192	L	
61	H-897	6.00	24.25	24.7422	L	
61	H-898	6.25	23.85	26.2054	L	
61	H-907	5.70	23.45	24.3070	L	
61	H-911	6.50	24.95	26.0521	L	
61	LACMHC-12796	6.60	24.10	27.3858	R	
61	LACMHC-12799	6.30	24.40	25.8196	R	
61	LACMHC-12800	6.70	24.10	27.8008	R	
61	LACMHC-12802	6.60	24.20	27.2727	R	
61	LACMHC-12804	6.05	27.15	22.2836	R	

Table 17

C. dirus femur statistics (Pit 60)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
60	H-411	6.90	24.70	27.9352	L	
60	H-412	6.00	24.25	24.7422	R	
60	H-497	6.20	24.25	25.5670	R	
60	H-596	6.65	25.45	26.1296	L	
60	H-602	5.70	23.30	24.4635	L	
60	LACMHC-12770	4.40	14.50	30.3448	L	ends not fused

Table 18

C. dirus femur statistics (Pit 16)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
16	H-273	6.40	23.85	26.8343	R	
16	H-277	6.30	24.80	25.4032	R	
16	H-546	6.40	24.80	25.8064	R	
16	H-547	6.70	24.75	27.0707	R	
16	H-785	6.40	23.75	26.9473	L	
16	H-877	6.30	24.90	25.3012	L	

Table 19

C. dirus femur statistics (Pit 67)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
67	H-246	6.15	23.65	26.0042	R	
67	H-253	6.10	24.45	24.9488	R	
67	H-254	6.40	24.30	26.3374	R	
67	H-269	6.30	24.05	26.1954	R	
67	H-280	6.00	25.15	23.8568	R	
67	H-286	6.05	23.90	25.3138	R	
67	H-322	5.95	23.95	24.8434	R	
67	H-338	6.00	25.15	23.8568	R	
67	H-362	6.25	25.30	24.7035	R	
67	H-363	6.00	24.85	24.1448	R	
67	H-365	6.55	24.75	26.4646	R	
67	H-369	6.20	24.80	25.0000	R	
67	H-372	6.40	23.70	27.0042	R	
67	H-373	5.80	23.15	25.0539	R	
67	H-376	6.10	24.80	24.5967	R	
67	H-380	6.45	24.85	25.9557	R	
67	H-381	6.40	24.90	25.7028	R	
67	H-387	5.75	22.95	25.0544	R	
67	H-388	6.40	24.35	26.2833	R	
67	H-393	6.00	22.95	26.1437	R	
67	H-396	5.90	23.55	25.0530	R	
67	H-398	6.00	24.55	24.4399	R	
67	H-399	6.30	24.90	25.3012	R	

(Continued on next page)

Table 19 (continued)

67	H-402	5.60	23.45	23.8805	R	
67	H-403	6.35	23.90	26.5690	R	
67	H-404	5.75	23.80	24.1596	R	
67	H-405	6.05	23.40	25.8547	R	
67	H-406	6.95	25.75	26.9902	R	
67	H-407	6.30	26.00	24.2307	R	
67	H-408	6.00	22.90	26.2008	R	
67	H-431	5.85	23.35	25.0535	R	
67	H-434	6.10	24.15	25.2587	R	
67	H-435	5.95	23.50	25.3191	R	
67	H-440	5.95	24.10	24.6887	R	
67	H-441	6.40	25.10	25.4980	R	
67	H-442	5.95	25.05	23.7524	R	
67	H-445	6.00	23.50	25.5319	R	
67	H-446	6.20	24.20	25.6198	R	
67	H-458	6.85	23.25	29.4623	R	
67	H-469	6.00	25.05	23.9520	R	
67	H-473	5.80	23.35	24.8394	R	
67	H-500	6.65	25.50	26.0784	R	
67	H-501	6.60	22.70	29.0748	R	
67	H-535	6.45	24.70	26.1133	R	
67	H-536	5.65	22.60	25.0000	R	
67	H-537	6.20	23.40	26.4957	R	
67	H-538	5.90	23.20	25.4310	R	
67	H-539	6.30	25.85	24.3713	R	
67	H-561	5.60	22.65	24.7240	L	

(Continued on next page)

Table 19 (continued)

67	H-562	6.45	25.90	24.9034	L	
67	H-566	6.00	25.05	23.9520	L	
67	H-568	5.70	23.50	24.2553	L	
67	H-569	6.20	23.40	26.4957	L	
67	H-571	6.15	23.90	25.7322	L	
67	H-573	6.30	23.55	26.7515	L	
67	H-576	5.70	23.20	24.5689	L	
67	H-578	6.00	23.40	25.6410	L	
67	H-579	6.20	22.60	27.4336	L	
67	H-586	6.50	26.10	24.9042	L	
67	H-590	5.45	22.80	23.9035	L	
67	H-594	6.20	25.45	24.3614	L	
67	H-599	6.05	25.05	24.1516	L	
67	H-601	6.20	23.50	26.3829	L	
67	H-604	6.25	25.20	24.8015	L	
67	H-607	6.80	22.95	29.6296	L	
67	H-609	6.10	24.00	25.4166	L	
67	H-610	6.45	23.80	27.1008	L	
67	H-615	5.90	24.20	24.3801	L	
67	H-616	6.10	24.90	24.4979	L	
67	H-623	6.40	25.30	25.2964	L	
67	H-640	6.50	25.40	25.5905	L	
67	H-669	6.00	24.95	24.0480	L	
67	H-699	5.80	23.70	24.4725	L	
67	H-709	6.30	24.60	25.6097	L	
67	H-722	6.00	24.20	24.7933	L	

(Continued on next page)

Table 19 (continued)

67	H-743	5.80	24.00	24.1666	L	
67	H-761	6.40	25.20	25.3968	L	
67	H-763	5.60	22.55	24.8337	L	
67	H-781	6.00	23.65	25.3699	L	
67	H-783	6.70	25.80	25.9689	L	
67	H-784	6.55	24.10	27.1784	L	
67	H-796	6.05	25.60	23.6328	L	
67	H-807	6.20	25.25	24.5544	L	
67	H-813	6.15	23.80	25.8403	L	
67	H-821	6.80	24.35	27.9260	L	
67	H-826	6.00	24.80	24.1935	L	
67	H-828	6.10	23.70	25.7383	L	
67	H-832	7.10	25.75	27.5728	L	
67	H-842	6.05	24.20	25.0000	L	
67	H-844	6.40	26.00	24.6153	L	
67	H-860	6.20	23.75	26.1052	L	
67	H-866	6.75	24.90	27.1084	L	
67	H-878	5.90	24.60	23.9837	L	
67	H-882	6.10	23.35	26.1241	L	
67	H-884	6.30	24.10	26.1410	L	
67	H-885	6.00	23.80	25.2100	L	
67	H-889	6.75	25.95	26.0115	L	
67	H-905	6.60	25.95	25.4335	L	
67	H-906	6.10	24.20	25.2066	L	
67	H-912	5.80	23.55	24.6284	L	
67	LACMHC-12798	5.35	22.50	23.7777	R	

Table 20

C. dirus femur statistics (Pit 77)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
77	H-235	6.70	26.35	25.4269	R	
77	H-239	6.00	24.25	24.7422	R	
77	H-247	6.25	25.45	24.5579	R	
77	H-288	6.70	24.55	27.2912	R	
77	H-318	6.10	23.25	26.2365	R	
77	H-346	6.50	24.90	26.1044	R	
77	H-397	5.90	24.90	23.6947	R	
77	H-409	6.45	25.10	25.6972	L	
77	H-410	6.20	24.40	25.4098	R	
77	H-480	6.10	23.85	25.5765	R	
77	H-487	6.30	24.40	25.8196	R	
77	H-502	5.65	24.25	23.2989	R	
77	H-503	6.00	25.20	23.8095	R	
77	H-540	5.95	24.05	24.7401	R	
77	H-592	6.55	25.30	25.8893	L	
77	H-598	7.10	25.20	28.1746	L	
77	H-713	6.30	25.95	24.2774	L	
77	H-715	6.45	23.90	26.9874	L	
77	H-766	6.20	25.30	24.5059	L	
77	H-806	5.70	23.95	23.7995	L	
77	H-814	6.80	26.40	25.7575	L	
77	H-816	6.45	26.25	24.5714	L	
77	H-835	6.70	26.10	25.6704	L	

(Continued on next page)

Table 20 (continued)

77	H-849	6.15	24.10	25.5186	L	
77	H-863	6.60	25.35	26.0355	L	
77	H-880	6.10	24.05	25.3638	L	
77	LACMHC-12769	5.05	17.20	29.3604	L	
77	LACMHC-12774	6.95	25.80	26.9379	L	
77	LACMHC-12806	6.95	26.45	26.2759	R	

Table 21

C. dirus femur statistics (Pit 90)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
90	H-621	6.50	22.75	28.5714	L	

Table 22

C. dirus femur statistics (Pit 91)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100		Notes
91	H-870	6.10	24.20	25.2066	L	

Table 23

C. dirus femur statistics (Pit N/A)

Pit	Specimen #	Circumference at midshaft	length	(circumference/length)*100			Notes
				Measured	Adjusted		(**juvenile)
n/a	H-427	5.90	25.10	23.5059		R	
n/a	H-433	5.80	24.60	23.5772		R	
n/a	H-481	5.80	25.00	23.2000		R	
n/a	H-488	6.55	27.70	23.6462		R	
n/a	H-489	6.10	24.55	24.8472		R	
n/a	H-490	5.90	23.15	25.4859		R	
n/a	H-491	6.35	24.70	25.7085		R	
n/a	H-493	6.60	25.65	25.7309		R	
n/a	H-558	6.20	25.30	24.5059		R	
n/a	H-559	6.30	24.45	25.7668		R	
n/a	H-624	7.35	26.20	28.0534		L	
n/a	H-629	6.30	23.60	26.6949		L	
n/a	H-631	6.00	24.30	24.6913		L	
n/a	H-837	6.30	25.25	24.9504		L	
n/a	H-852	5.90	24.55	24.0325		L	
n/a	LACMHC-87115	4.95	17.20	28.7790	19.3920	R	** no fusion
n/a	LACMHC-87566	6.10	24.40	25.0000		L	
n/a	LACMHC-87567	5.50	22.40	24.5535		L	
n/a	LACMHC-87568	6.00	23.25	25.8064		L	
n/a	LACMHC-87569	6.75	23.65	28.5412		L	
n/a	LACMHC-87570	6.40	24.80	25.8064		L	

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Table 23 (continued)

n/a	LACMHC-87571	5.90	22.70	25.9911		L	
n/a	LACMHC-87572	6.50	25.35	25.6410		L	
n/a	LACMHC-87573	5.95	23.20	25.6465		L	femur head missing (pic 7)
n/a	LACMHC-87677	5.50	18.80	29.2553		L	Unfused, broken
n/a	LACMHC-87681	5.20	17.30	30.0578		L	Unfused, broken
n/a	LACMHC-87682	5.40	17.55	30.7692		L	Unfused, broken
n/a	LACMHC-87683	4.70	14.75	31.8644		L	Unfused, broken
n/a	LACMHC-87730	6.75	25.50	26.4705		L	
n/a	LACMHC-87731	6.10	24.45	24.9488		L	
n/a	LACMHC-87732	6.40	24.75	25.8585		L	
n/a	LACMHC-87733	6.50	24.20	26.8595		L	
n/a	LACMHC-87734	6.35	25.80	24.6124		L	
n/a	LACMHC-87735	5.60	24.75	22.6262		L	
n/a	LACMHC-87736	6.10	24.70	24.6963		L	
n/a	LACMHC-87737	6.30	25.45	24.7544		L	
n/a	LACMHC-87738	6.40	24.90	25.7028		L	
n/a	LACMHC-87740	6.00	23.60	25.4237		L	
n/a	LACMHC-87741	6.65	25.40	26.1811		L	
n/a	LACMHC-87742	6.00	24.35	24.6406		L	
n/a	LACMHC-87743	6.45	24.50	26.3265		L	
n/a	LACMHC-87744	6.95	23.60	29.4491		L	
n/a	LACMHC-87745	5.65	23.30	24.2489		L	
n/a	LACMHC-87746	5.60	23.35	23.9828		L	
n/a	LACMHC-87750	5.70	23.55	24.2038		L	
n/a	LACMHC-87751	6.00	23.60	25.4237		L	
n/a	LACMHC-87752	6.80	24.45	27.8118		L	

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Table 23 (continued)

n/a	LACMHC-87753	6.20	24.15	25.6728		L	
n/a	LACMHC-87754	6.10	25.85	23.5976		L	
n/a	LACMHC-87755	6.70	23.60	28.3898		L	
n/a	LACMHC-87756	5.10	22.45	22.7171		L	
n/a	LACMHC-87757	5.90	24.20	24.3801		L	
n/a	LACMHC-87760	6.30	24.35	25.8726	26.1330	L	proximal end not fused (pic 6)
n/a	LACMHC-87761	6.95	22.65	30.6843	25.5365	L	both ends not fused
n/a	LACMHC-87762	5.90	22.75	25.9340	25.6493	L	both ends not fused
n/a	LACMHC-87763	5.50	22.55	24.3902	25.4238	L	both ends not fused
n/a	LACMHC-87764	6.45	23.50	27.4468	26.4949	L	both ends not fused
n/a	LACMHC-87765	6.05	27.85	21.7235	31.3992	L	both ends not fused
n/a	LACMHC-87766	5.90	24.20	24.3801	25.9720	L	proximal end not fused
n/a	LACMHC-87767	5.80	22.00	26.3636	23.6109	L	proximal end not fused
n/a	LACMHC-87768	6.05	23.35	25.9100	25.0598	L	proximal end not fused
n/a	LACMHC-87769	6.55	24.35	26.8993	26.1330	L	proximal end not fused
n/a	LACMHC-87770	6.20	24.35	25.4620	26.1330	L	proximal end not fused
n/a	LACMHC-87771	6.00	25.15	23.8568		L	
n/a	LACMHC-87772	5.90	24.05	24.5322	25.8110	L	proximal end not fused
n/a	LACMHC-87773	6.10	23.55	25.9023	25.2744	L	proximal end not fused
n/a	LACMHC-87774	6.35	24.35	26.0780	26.1330	L	proximal end not fused
n/a	LACMHC-87775	6.00	25.05	23.9520	26.8843	L	proximal end not fused
n/a	LACMHC-87776	5.80	23.40	24.7863	25.1135	L	proximal end not fused
n/a	LACMHC-87777	6.40	25.25	25.3465	27.0989	L	proximal end not fused
n/a	LACMHC-87778	5.90	24.35	24.2299	26.1330	L	proximal end not fused
n/a	LACMHC-87780	5.50	22.25	24.7191	23.8792	L	proximal end not fused
n/a	LACMHC-87781	5.10	23.00	22.1739	24.6842	L	proximal end not fused

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Table 23 (continued)

n/a	LACMHC-87782	6.50	23.80	27.3109	25.5427	L	proximal end not fused
n/a	LACMHC-87783	5.75	23.45	24.5202	25.1671	L	proximal end not fused
n/a	LACMHC-87784	5.80	23.15	25.0539	24.8451	L	proximal end not fused
n/a	LACMHC-87785	5.90	23.85	24.7379	25.5964	L	proximal end not fused
n/a	LACMHC-87786	6.20	23.80	26.0504	25.5427	L	proximal end not fused
n/a	LACMHC-87787	6.00	25.05	23.9520	26.8843	L	proximal end not fused
n/a	LACMHC-87788	5.60	22.50	24.8888	24.1475	L	proximal end not fused
n/a	LACMHC-87789	5.95	23.80	25.0000	25.5427	L	proximal end not fused
n/a	LACMHC-87790	5.80	23.00	25.2173	24.6842	L	proximal end not fused (pic 5)
n/a	LACMHC-87791	5.85	23.45	24.9466	25.1671	L	proximal end not fused
n/a	LACMHC-87792	6.45	24.10	26.7634	25.8647	L	proximal end not fused
n/a	LACMHC-87793	5.95	24.45	24.3353	26.2403	L	proximal end not fused
n/a	LACMHC-87794	6.35	25.25	25.1485	27.0989	L	proximal end not fused
n/a	LACMHC-87795	5.60	23.00	24.3478	24.6842	L	proximal end not fused
n/a	LACMHC-87797	5.85	20.15	29.0322	22.7179	L	** no fusion
n/a	LACMHC-87798	5.70	20.90	27.2727	23.5635	L	** no fusion
n/a	LACMHC-87801	5.50	20.15	27.2952	22.7179	L	** no fusion
n/a	LACMHC-87802	5.85	19.85	29.4710	22.3797	L	** no fusion
n/a	LACMHC-87806	5.00	18.60	26.8817	20.9704	L	** no fusion
n/a	LACMHC-87807	5.95	19.90	29.8994	22.4361	L	** no fusion
n/a	LACMHC-87810	5.90	20.45	28.8508	23.0562	L	** no fusion
n/a	LACMHC-87814	5.30	20.70	25.6038	23.3380	L	** no fusion
n/a	LACMHC-87815	5.80	20.55	28.2238	23.1689	L	** no fusion
n/a	LACMHC-87816	5.50	21.10	26.0663	23.7890	L	** no fusion
n/a	LACMHC-87817	5.90	20.60	28.6407	23.2253	L	** no fusion
n/a	LACMHC-87818	5.80	20.85	27.8177	23.5071	L	** no fusion

(Continued on next page)

Table 23 (continued)

n/a	LACMHC-87819	6.15	21.65	28.4064	24.4091	L	** no fusion
n/a	LACMHC-87820	6.15	22.70	27.0925	25.5929	L	** no fusion
n/a	LACMHC-87821	6.00	27.00	22.2222	30.4409	L	** no fusion
n/a	LACMHC-87822	6.05	23.50	25.7446	26.4949	L	** no fusion
n/a	LACMHC-87823	6.35	21.70	29.2626	24.4655	L	** no fusion
n/a	LACMHC-87824	5.65	22.00	25.6818	24.8037	L	** no fusion
n/a	LACMHC-87825	5.85	22.30	26.2331	25.1419	L	** no fusion
n/a	LACMHC-87826	5.85	20.80	28.1250	23.4508	L	** no fusion
n/a	LACMHC-87827	5.70	21.70	26.2672	24.4655	L	** no fusion
n/a	LACMHC-87828	5.80	22.20	26.1261	25.0292	L	** no fusion
n/a	LACMHC-87829	5.55	21.55	25.7540	24.2963	L	** no fusion
n/a	LACMHC-87830	5.85	20.25	28.8888	22.8307	L	** no fusion
n/a	LACMHC-87832	5.75	22.10	26.0180	24.9164	L	** no fusion
n/a	LACMHC-87833	5.25	20.85	25.1798	23.5071	L	** no fusion
n/a	LACMHC-87834	5.60	21.20	26.4150	23.9017	L	** no fusion
n/a	LACMHC-87835	5.55	20.85	26.6187	23.5071	L	** no fusion
n/a	LACMHC-87836	5.60	20.85	26.8585	23.5071	L	** no fusion
n/a	LACMHC-87837	5.65	21.05	26.8408	23.7326	L	** no fusion
n/a	LACMHC-87838	5.65	20.30	27.8325	22.8870	L	** no fusion
n/a	LACMHC-87839	5.50	20.85	26.3788	23.5071	L	** no fusion
n/a	LACMHC-87840	5.40	19.30	27.9792	21.7596	L	** no fusion
n/a	LACMHC-87841	5.85	19.75	29.6202	22.2669	L	** no fusion
n/a	LACMHC-87842	5.50	19.80	27.7777	22.3233	L	** no fusion
n/a	LACMHC-87843	5.70	18.95	30.0791	21.3650	L	** no fusion
n/a	LACMHC-87844	5.55	19.90	27.8894	22.4361	L	** no fusion
n/a	LACMHC-87845	5.30	18.60	28.4946	20.9704	L	** no fusion

(Continued on next page)

Table 23 (continued)

n/a	LACMHC-87846	5.55	19.60	28.3163	22.0978	L	** no fusion
n/a	LACMHC-87847	5.45	19.65	27.7353	22.1542	L	** no fusion
n/a	LACMHC-87848	5.10	18.50	27.5675	20.8576	L	** no fusion
n/a	LACMHC-87849	5.00	17.55	28.4900	19.7866	L	** no fusion
n/a	LACMHC-87850	6.00	22.10	27.1493	24.9164	L	** no fusion
n/a	LACMHC-87851	5.80	19.00	30.5263	21.4214	L	** no fusion
n/a	LACMHC-87853	5.10	18.80	27.1276	21.1959	L	** no fusion
n/a	LACMHC-87854	5.80	19.65	29.5165	22.1542	L	** no fusion
n/a	LACMHC-87855	5.60	21.60	25.9259	24.3527	L	** no fusion
n/a	LACMHC-87856	5.55	21.50	25.8139	24.2400	L	** no fusion
n/a	LACMHC-87857	5.60	21.20	26.4150	23.9017	L	** no fusion
n/a	LACMHC-87858	5.90	21.60	27.3148	24.3527	L	** no fusion
n/a	LACMHC-87860	5.30	20.10	26.3681	22.6615	L	** no fusion
n/a	LACMHC-87862	5.50	20.45	26.8948	23.0562	L	** no fusion
n/a	LACMHC-87863	5.80	20.15	28.7841	22.7179	L	** no fusion
n/a	LACMHC-87864	5.20	19.75	26.3291	22.2669	L	** no fusion
n/a	LACMHC-87865	5.40	19.55	27.6214	22.0415	L	** no fusion
n/a	LACMHC-87866	5.40	21.15	25.5319	23.8454	L	** no fusion
n/a	LACMHC-87867	5.80	20.40	28.4313	22.9998	L	** no fusion
n/a	LACMHC-87868	5.75	21.20	27.1226	23.9017	L	** no fusion
n/a	LACMHC-87870	5.45	20.70	26.3285	23.3380	L	** no fusion
n/a	LACMHC-87871	5.50	18.30	30.0546	20.6322	L	** no fusion
n/a	LACMHC-87872	5.60	18.60	30.1075	20.9704	L	** no fusion
n/a	LACMHC-87873	5.10	18.70	27.2727	21.0831	L	** no fusion
n/a	LACMHC-87874	5.75	18.75	30.6666	21.1395	L	** no fusion
n/a	LACMHC-87875	5.15	18.50	27.8378	20.8576	L	** no fusion

(Continued on next page)

Table 23 (continued)

n/a	LACMHC-87876	4.90	16.90	28.9940	19.0537	L	** no fusion
n/a	LACMHC-87877	5.30	19.10	27.7486	21.5341	R	** no fusion
n/a	LACMHC-87878	5.35	19.00	28.1578	21.4214	L	** no fusion
n/a	LACMHC-87879	4.95	16.95	29.2035	19.1101	R	** no fusion
n/a	LACMHC-87887	4.40	19.50	22.5641	21.9851	L	** no fusion
n/a	LACMHC-87889	4.70	15.90	29.5597	17.9263	L	** no fusion
n/a	LACMHC-87890	4.30	13.70	31.3868	15.4459	R	** no fusion
n/a	LACMHC-87891	4.10	13.80	29.7101	15.5587	L	** no fusion
n/a	LACMHC-87892	4.30	13.75	31.2727	15.5023	R	** no fusion
n/a	LACMHC-87894	5.10	17.30	29.4797	19.5047	L	** no fusion
n/a	LACMHC-87895	4.85	15.85	30.5993	17.8699	L	** no fusion
n/a	LACMHC-87896	4.85	15.10	32.1192	17.0243	L	** no fusion
n/a	LACMHC-87897	5.20	15.75	33.0158	17.7572	R	** no fusion
n/a	LACMHC-87898	4.65	19.20	24.2187	21.6469	L	** no fusion
n/a	LACMHC-87899	5.75	14.65	39.2491	16.5170	R	** no fusion
n/a	LACMHC-87901	4.40	11.15	39.4618	12.5709	L	** no fusion
n/a	LACMHC-87902	4.70	16.80	27.9761	18.9410	L	** no fusion
n/a	LACMHC-87903	5.60	16.15	34.6749	18.2082	R	** no fusion
n/a	LACMHC-87904	4.85	15.45	31.3915	17.4189	L	** no fusion
n/a	LACMHC-87905	4.90	16.70	29.3413	18.8282	R	** no fusion
n/a	LACMHC-87906	4.90	16.35	29.9694	18.4336	L	** no fusion
n/a	LACMHC-87907	5.10	17.00	30.0000	19.1665	R	** no fusion
n/a	LACMHC-87908	5.10	17.55	29.0598	19.7866	L	** no fusion
n/a	LACMHC-87910	4.55	15.40	29.5454	17.3626	R	** no fusion
n/a	LACMHC-87911	4.70	17.95	26.1838	20.2375	L	** no fusion
n/a	LACMHC-87913	5.10	18.75	27.2000	21.1395	L	** no fusion

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Table 23 (continued)

n/a	LACMHC-87916	5.00	17.60	28.4090	19.8429	R	** no fusion
n/a	LACMHC-87917	5.10	17.85	28.5714	20.1248	L	** no fusion
n/a	LACMHC-87918	4.75	17.15	27.6967	19.3356	L	** no fusion
n/a	LACMHC-87919	4.85	16.65	29.1291	18.7719	R	** no fusion
n/a	LACMHC-87920	5.10	15.65	32.5878	17.6444	L	** no fusion
n/a	LACMHC-87921	5.20	19.35	26.8733	21.8160	L	** no fusion
n/a	LACMHC-87922	5.35	17.60	30.3977	19.8429	R	** no fusion
n/a	LACMHC-87923	4.95	15.20	32.5657	17.1371	L	** no fusion
n/a	LACMHC-87924	5.05	15.00	33.6666	16.9116	L	** no fusion
n/a	LACMHC-87925	4.45	16.00	27.8125	18.0390	R	** no fusion
n/a	LACMHC-87926	4.80	17.10	28.0701	19.2792	L	** no fusion
n/a	LACMHC-87927	5.10	17.05	29.9120	19.2228	R	** no fusion
n/a	LACMHC-87928	4.75	15.90	29.8742	17.9263	L	** no fusion
n/a	LACMHC-87929	5.30	19.15	27.6762	21.5905	R	** no fusion
n/a	LACMHC-87931	4.65	17.35	26.8011	19.5611	L	** no fusion
n/a	LACMHC-87932	5.15	17.75	29.0140	20.0121	R	** no fusion
n/a	LACMHC-87933	5.70	18.20	31.3186	20.5194	L	** no fusion
n/a	LACMHC-87935	5.05	15.55	32.4758	17.5317	L	** no fusion
n/a	LACMHC-87936	5.25	19.30	27.2020	21.7596	R	** no fusion
n/a	LACMHC-87937	5.40	18.75	28.8000	21.1395	R	** no fusion
n/a	LACMHC-87938	5.40	18.35	29.4277	20.6885	R	** no fusion
n/a	LACMHC-87939	5.90	18.20	32.4175	20.5194	R	** no fusion
n/a	LACMHC-87940	5.65	18.95	29.8153	21.3650	R	** no fusion
n/a	LACMHC-87941	4.90	18.90	25.9259	21.3086	R	** no fusion
n/a	LACMHC-87942	5.20	18.15	28.6501	20.4630	R	** no fusion
n/a	LACMHC-87943	5.55	18.35	30.2452	20.6885	L	** no fusion

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Table 23 (continued)

n/a	LACMHC-87944	5.40	18.10	29.8342	20.4067	R	** no fusion
n/a	LACMHC-87945	5.40	18.75	28.8000	21.1395	L	** no fusion
n/a	LACMHC-87946	6.00	18.85	31.8302	21.2522	R	** no fusion
n/a	LACMHC-87947	5.10	15.95	31.9749	17.9827	L	** no fusion
n/a	LACMHC-87948	5.60	19.30	29.0155	21.7596	L	** no fusion
n/a	LACMHC-87949	5.60	20.85	26.8585	23.5071	L	** no fusion
n/a	LACMHC-87950	5.10	18.95	26.9129	21.3650	R	** no fusion
n/a	LACMHC-87951	5.40	19.45	27.7634	21.9287	R	** no fusion
n/a	LACMHC-87952	5.00	19.75	25.3164	22.2669	L	** no fusion
n/a	LACMHC-87953	5.90	20.90	28.2296	23.5635	L	** no fusion
n/a	LACMHC-87954	5.30	15.90	33.3333	17.9263	L	** no fusion
n/a	LACMHC-87955	5.90	15.55	37.9421	17.5317	L	** no fusion
n/a	LACMHC-87956	5.65	13.55	41.6974	15.2768	L	** no fusion
n/a	LACMHC-87957	5.30	19.20	27.6041	21.6469	L	** no fusion
n/a	LACMHC-87958	5.55	19.45	28.5347	21.9287	R	** no fusion
n/a	LACMHC-87959	6.20	18.05	34.3490	20.3503	R	** no fusion
n/a	LACMHC-87960	4.90	16.30	30.0613	18.3773	L	** no fusion
n/a	LACMHC-87988	4.70	20.30	23.1527	22.8870	L	** no fusion
n/a	LACMHC-88042	6.10	24.30	25.1028		L	
n/a	LACMHC-88186	6.70	25.25	26.5346		R	
n/a	LACMHC-88187	6.20	24.80	25.0000		R	
n/a	LACMHC-88188	6.05	24.70	24.4939		R	
n/a	LACMHC-88189	5.80	24.20	23.9669		R	
n/a	LACMHC-88190	6.45	23.70	27.2151		R	
n/a	LACMHC-88191	5.70	23.95	23.7995		R	
n/a	LACMHC-88192	6.50	23.70	27.4261		R	

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Table 23 (continued)

n/a	LACMHC-88193	6.90	25.20	27.3809		R	
n/a	LACMHC-88194	6.25	25.00	25.0000		R	
n/a	LACMHC-88195	6.00	24.10	24.8962		R	
n/a	LACMHC-88196	5.50	23.85	23.0607		R	
n/a	LACMHC-88197	6.90	25.30	27.2727		R	
n/a	LACMHC-88198	5.90	25.10	23.5059		R	
n/a	LACMHC-88200	5.90	23.95	24.6346		R	femur head missing
n/a	LACMHC-88362	6.45	24.90	25.9036		R	femur head worn
n/a	LACMHC-88365	6.20	22.90	27.0742		R	femur head worn
n/a	LACMHC-88370	6.35	24.55	25.8655		R	femur head worn
n/a	LACMHC-88371	6.50	23.90	27.1966		R	femur head worn
n/a	LACMHC-88372	6.10	24.20	25.2066		R	femur head worn
n/a	LACMHC-88374	6.40	24.00	26.6666		R	
n/a	LACMHC-88375	6.15	24.30	25.3086		R	
n/a	LACMHC-88376	5.60	23.70	23.6286		R	
n/a	LACMHC-88377	5.80	24.70	23.4817		R	proximal epiphysis worn off
n/a	LACMHC-88378	6.20	25.35	24.4575		R	
n/a	LACMHC-88379	6.05	24.70	24.4939		R	
n/a	LACMHC-88380	5.50	22.50	24.4444		R	
n/a	LACMHC-88381	5.60	21.60	25.9259		R	
n/a	LACMHC-88382	6.00	24.00	25.0000		R	Proximal epiphysis worn off
n/a	LACMHC-88383	5.90	25.10	23.5059		R	
n/a	LACMHC-88384	6.30	23.60	26.6949		R	
n/a	LACMHC-88385	6.75	24.80	27.2177		R	
n/a	LACMHC-88386	6.00	24.40	24.5901		R	
n/a	LACMHC-88387	6.45	24.55	26.2729		R	

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Table 23 (continued)

n/a	LACMHC-88388	6.20	24.10	25.7261		R	
n/a	LACMHC-88389	6.50	23.40	27.7777		R	
n/a	LACMHC-88390	5.95	24.60	24.1869	25.1655	R	** femur head missing
n/a	LACMHC-88391	6.00	23.70	25.3164	24.2448	R	** femur head missing
n/a	LACMHC-88392	5.80	23.60	24.5762	24.1425	R	** femur head missing
n/a	LACMHC-88393	6.05	23.60	25.6355	24.1425	R	** femur head missing
n/a	LACMHC-88394	5.80	23.85	24.3186	24.3982	R	** femur head missing
n/a	LACMHC-88395	6.00	23.70	25.3164	24.2448	R	** femur head missing
n/a	LACMHC-88396	5.90	23.50	25.1063	25.2208	R	** proximal end missing
n/a	LACMHC-88397	6.40	23.90	26.7782	25.6501	R	** proximal end missing
n/a	LACMHC-88398	5.80	22.85	25.3829	24.5232	R	** proximal end missing
n/a	LACMHC-88399	5.70	23.45	24.3070	23.9890	R	** femur head missing
n/a	LACMHC-88400	5.80	23.10	25.1082	23.6310	R	** femur head missing
n/a	LACMHC-88401	6.20	24.80	25.0000	25.3701	R	** femur head missing
n/a	LACMHC-88402	6.40	23.05	27.7657	23.5798	R	** femur head missing
n/a	LACMHC-88403	6.20	24.85	24.9496	25.4212	R	** femur head missing
n/a	LACMHC-88404	5.85	23.65	24.7357	24.1936	R	** femur head missing
n/a	LACMHC-88407	5.80	22.75	25.4945	23.2729	R	** femur head missing
n/a	LACMHC-88409	5.55	22.10	25.1131	22.6080	R	** femur head missing
n/a	LACMHC-88410	5.90	23.90	24.6861	24.4494	R	** femur head missing
n/a	LACMHC-88411	6.20	23.20	26.7241	23.7333	R	** femur head missing
n/a	LACMHC-88412	5.90	22.60	26.1061	23.1195	R	** femur head missing
n/a	LACMHC-88413	6.30	22.85	27.5711	23.3752	R	** femur head missing
n/a	LACMHC-88414	6.10	23.20	26.2931	23.7333	R	** femur head missing
n/a	LACMHC-88415	5.70	22.45	25.3897	24.0939	R	** proximal end missing
n/a	LACMHC-88416	5.45	22.25	24.4943	23.8792	R	** proximal end missing

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Table 23 (continued)

n/a	LACMHC-88417	5.35	21.35	25.0585	24.0709	R	** no fusion
n/a	LACMHC-88418	5.80	22.00	26.3636	24.8037	R	** no fusion
n/a	LACMHC-88420	5.75	20.55	27.9805	23.1689	R	** no fusion
n/a	LACMHC-88421	5.90	21.55	27.3781	24.2963	R	** no fusion
n/a	LACMHC-88422	5.70	21.10	27.0142	23.7890	R	** no fusion
n/a	LACMHC-88423	5.65	20.10	28.1094	22.6615	R	** no fusion
n/a	LACMHC-88424	5.30	20.35	26.0442	22.9434	R	** no fusion
n/a	LACMHC-88425	6.00	20.90	28.7081	23.5635	R	** no fusion
n/a	LACMHC-88426	6.20	22.20	27.9279	25.0292	R	** no fusion
n/a	LACMHC-88428	5.60	21.80	25.6880	24.5782	R	** no fusion
n/a	LACMHC-88429	5.30	18.95	27.9683	21.3650	R	** no fusion
n/a	LACMHC-88430	5.60	21.60	25.9259	24.3527	R	** no fusion
n/a	LACMHC-88431	5.50	20.85	26.3788	23.5071	R	** no fusion
n/a	LACMHC-88432	5.80	21.55	26.9141	24.2963	R	** no fusion
n/a	LACMHC-88434	6.00	22.05	27.2108	23.0843	R	** femur head and distal epiphysis missing
n/a	LACMHC-88435	6.00	20.75	28.9156	23.3944	R	** no fusion
n/a	LACMHC-88436	6.05	21.50	28.1395	24.2400	R	** no fusion
n/a	LACMHC-88437	5.60	21.50	26.0465	24.2400	R	** no fusion
n/a	LACMHC-88438	5.80	20.30	28.5714	22.8870	R	** no fusion
n/a	LACMHC-88439	6.15	20.30	30.2955	22.8870	R	** no fusion
n/a	LACMHC-88440	5.75	19.60	29.3367	22.0978	R	** no fusion
n/a	LACMHC-88441	6.00	20.25	29.6296	22.8307	R	** no fusion
n/a	LACMHC-88444	5.30	20.70	25.6038	23.3380	R	** no fusion
n/a	LACMHC-88445	5.40	20.50	26.3414	23.1125	R	** no fusion
n/a	LACMHC-88453	5.25	19.00	27.6315	21.4214	R	** no fusion

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Table 23 (continued)

n/a	LACMHC-88451	5.90	21.25	27.7647	22.2468	R	** femur head and distal epiphysis missing
n/a	LACMHC-88452	5.60	21.80	25.6880	22.8226	R	** femur head and distal epiphysis missing
n/a	LACMHC-88454	5.50	19.65	27.9898	22.1542	R	** no fusion
n/a	LACMHC-88455	4.80	18.55	25.8760	20.9140	R	** no fusion
n/a	LACMHC-88456	5.05	18.35	27.5204	20.6885	R	** no fusion
n/a	LACMHC-88460	5.30	19.50	27.1794	21.9851	R	** no fusion
n/a	LACMHC-88461	5.80	20.40	28.4313	22.9998	R	** no fusion
n/a	LACMHC-88462	5.60	21.20	26.4150	23.9017	R	** no fusion
n/a	LACMHC-88463	5.50	21.50	25.5813	24.2400	R	** no fusion
n/a	LACMHC-88464	5.85	20.85	28.0575	23.5071	R	** no fusion
n/a	LACMHC-88465	5.70	21.20	26.8867	23.9017	R	** no fusion
n/a	LACMHC-88468	5.95	20.00	29.7500	22.5488	R	** no fusion
n/a	LACMHC-88469	5.40	20.90	25.8373	23.5635	R	** no fusion
n/a	LACMHC-88469	5.90	21.20	27.8301	23.9017	R	** no fusion
n/a	LACMHC-88483	5.50	22.20	24.7747	25.0292	R	** no fusion
n/a	LACMHC-88484	5.40	19.65	27.4809	22.1542	R	** no fusion
n/a	LACMHC-88484	5.90	20.70	28.5024	23.3380	R	** no fusion
n/a	LACMHC-88485	5.40	19.90	27.1356	22.4361	R	** no fusion
n/a	LACMHC-88486	5.35	18.30	29.2349	20.6322	R	** no fusion
n/a	LACMHC-88487	5.60	19.55	28.6445	22.0415	R	** no fusion
n/a	LACMHC-88488	5.60	18.65	30.0268	21.0268	R	** no fusion
n/a	LACMHC-88490	5.20	20.00	26.0000	22.5488	R	** no fusion
n/a	LACMHC-88492	6.10	21.45	28.4382	24.1836	R	** no fusion
n/a	LACMHC-88493	6.50	21.20	30.6603	23.9017	R	** no fusion

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Table 23 (continued)

n/a	LACMHC-88495	5.50	20.05	27.4314	22.6052	R	** no fusion
n/a	LACMHC-88496	5.20	19.45	26.7352	21.9287	R	** no fusion
n/a	LACMHC-88497	5.35	19.20	27.8645	21.6469	R	** no fusion
n/a	LACMHC-88498	5.50	20.40	26.9607	22.9998	R	** no fusion
n/a	LACMHC-88499	5.35	18.20	29.3956	20.5194	R	** no fusion
n/a	LACMHC-88500	5.10	18.60	27.4193	20.9704	R	** no fusion
n/a	LACMHC-88501	5.85	21.00	27.8571	23.6762	R	** no fusion
n/a	LACMHC-88503	5.50	19.95	27.5689	22.4924	R	** no fusion
n/a	LACMHC-88504	5.50	20.60	26.6990	23.2253	R	** no fusion
n/a	LACMHC-88505	5.75	19.30	29.7927	21.7596	R	** no fusion
n/a	LACMHC-88506	5.30	18.90	28.0423	21.3086	R	** no fusion
n/a	LACMHC-88507	5.20	19.50	26.6666	21.9851	R	** no fusion
n/a	LACMHC-88508	5.35	18.60	28.7634	20.9704	R	** no fusion
n/a	LACMHC-88509	5.20	18.25	28.4931	20.5758	R	** no fusion
n/a	LACMHC-88510	6.20	21.10	29.3838	23.7890	R	** no fusion
n/a	LACMHC-88511	5.70	20.50	27.8048	23.1125	R	** no fusion
n/a	LACMHC-88513	5.30	19.70	26.9035	22.2106	R	** no fusion
n/a	LACMHC-88514	5.10	20.00	25.5000	22.5488	R	** no fusion
n/a	LACMHC-88515	5.65	19.10	29.5811	21.5341	R	** no fusion
n/a	LACMHC-88516	5.60	18.00	31.1111	20.2939	R	** no fusion
n/a	LACMHC-88517	5.55	17.95	30.9192	20.2375	R	** no fusion
n/a	LACMHC-88518	5.90	17.95	32.8690	20.2375	R	** no fusion
n/a	LACMHC-88522	5.00	18.70	26.7379	21.0831	R	** no fusion
n/a	LACMHC-88523	5.15	17.10	30.1169	19.2792	R	** no fusion
n/a	LACMHC-88524	5.00	18.15	27.5482	20.4630	R	** no fusion
n/a	LACMHC-88527	4.90	19.30	25.3886	21.7596	R	** no fusion

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Table 23 (continued)

n/a	LACMHC-88530	5.80	19.15	30.2872	21.5905	R	** no fusion
n/a	LACMHC-88532	5.30	18.20	29.1208	20.5194	R	** no fusion
n/a	LACMHC-88538	5.95	17.90	33.2402	20.1812	R	** no fusion
n/a	LACMHC-88539	4.70	16.50	28.4848	18.6028	R	** no fusion
n/a	LACMHC-88540	5.20	17.50	29.7142	19.7302	R	** no fusion
n/a	LACMHC-88541	5.10	17.55	29.0598	19.7866	R	** no fusion
n/a	LACMHC-88542	5.05	17.70	28.5310	19.9557	R	** no fusion
n/a	LACMHC-88543	5.50	17.75	30.9859	20.0121	R	** no fusion
n/a	LACMHC-88544	5.45	17.60	30.9659	19.8429	R	** no fusion
n/a	LACMHC-88545	5.10	16.90	30.1775	19.0537	R	** no fusion
n/a	LACMHC-88546	4.95	16.20	30.5555	18.2645	R	** no fusion
n/a	LACMHC-88547	5.30	16.65	31.8318	18.7719	R	** no fusion
n/a	LACMHC-88548	5.10	17.50	29.1428	19.7302	R	** no fusion
n/a	LACMHC-88550	4.75	16.05	29.5950	18.0954	R	** no fusion
n/a	LACMHC-88552	5.10	16.30	31.2883	18.3773	R	** no fusion
n/a	LACMHC-88553	5.05	17.45	28.9398	19.6738	R	** no fusion
n/a	LACMHC-88554	5.00	16.00	31.2500	18.0390	R	** no fusion
n/a	LACMHC-88555	5.05	15.95	31.6614	17.9827	R	** no fusion
n/a	LACMHC-88556	4.65	17.40	26.7241	19.6175	R	** no fusion
n/a	LACMHC-88557	4.90	16.15	30.3405	18.2082	R	** no fusion
n/a	LACMHC-88558	4.90	16.70	29.3413	18.8282	R	** no fusion
n/a	LACMHC-88559	5.35	16.90	31.6568	19.0537	R	** no fusion
n/a	LACMHC-88560	5.20	15.70	33.1210	17.7008	R	** no fusion
n/a	LACMHC-88561	5.30	15.95	33.2288	17.9827	R	** no fusion
n/a	LACMHC-88562	5.45	17.40	31.3218	19.6175	R	** no fusion
n/a	LACMHC-88563	4.95	15.95	31.0344	17.9827	R	** no fusion

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Table 23 (continued)

n/a	LACMHC-88564	5.65	17.70	31.9209	19.9557	R	** no fusion
n/a	LACMHC-88564	4.95	17.20	28.7790	19.3920	R	** no fusion
n/a	LACMHC-88565	5.20	17.40	29.8850	19.6175	R	** no fusion
n/a	LACMHC-88570	5.10	15.65	32.5878	17.6444	R	** no fusion
n/a	LACMHC-88572	5.35	16.95	31.5634	19.1101	R	** no fusion
n/a	LACMHC-88573	5.10	16.85	30.2670	18.9974	R	** no fusion
n/a	LACMHC-88574	5.10	15.75	32.3809	17.7572	R	** no fusion
n/a	LACMHC-88575	4.80	15.60	30.7692	17.5881	R	** no fusion
n/a	LACMHC-88577	4.40	15.55	28.2958	17.5317	R	** no fusion
n/a	LACMHC-88578	4.30	15.20	28.2894	17.1371	R	** no fusion
n/a	LACMHC-88580	4.75	15.10	31.4569	17.0243	R	** no fusion
n/a	LACMHC-88582	4.70	14.90	31.5436	16.7988	R	** no fusion
n/a	LACMHC-88583	4.95	13.60	36.3970	15.3332	R	** no fusion
n/a	LACMHC-88586	4.35	14.15	30.7420	15.9533	R	** no fusion
n/a	LACMHC-88588	3.90	12.90	30.2325	14.5440	R	** no fusion
n/a	LACMHC-88589	4.25	12.85	33.0739	14.4876	R	** no fusion
n/a	LACMHC-94587	5.10	18.60	27.4193	20.9704	R	** no fusion
n/a	LACMHC-94588	4.85	17.30	28.0346	19.5047	R	** no fusion
n/a	LACMHC-94590	5.05	18.90	26.7195	21.3086	R	** no fusion
n/a	LACMHC-94592	6.05	18.00	33.6111	20.2939	R	** no fusion
n/a	LACMHC-94593	4.55	16.75	27.1641	18.8846	R	** no fusion
n/a	LACMHC-94594	4.85	17.90	27.0949	20.1812	R	** no fusion
n/a	LACMHC-94595	4.90	17.30	28.3236	19.5047	R	** no fusion
n/a	LACMHC-94596	4.70	17.10	27.4853	19.2792	R	** no fusion
n/a	LACMHC-94598	4.65	16.45	28.2674	18.5464	R	** no fusion
n/a	LACMHC-94599	4.40	15.45	28.4789	17.4189	R	** no fusion

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Table 23 (continued)

n/a	LACMHC-97589	5.15	17.90	28.7709	20.1812	R	** no fusion
n/a	LACMHC-12725	6.20	23.10	26.8398		L	
n/a	LACMHC-12726	6.20	23.00	26.9565		L	
n/a	LACMHC-12727	5.85	24.55	23.8289		L	
n/a	LACMHC-12728	5.85	24.15	24.2236		L	
n/a	LACMHC-12729	6.30	24.30	25.9259		L	
n/a	LACMHC-12730	6.20	25.35	24.4575		L	
n/a	LACMHC-12731	6.80	24.70	27.5303		L	
n/a	LACMHC-12732	6.25	24.85	25.1509		L	
n/a	LACMHC-12733	6.75	24.95	27.0541		L	
n/a	LACMHC-12734	5.75	24.55	23.4215		L	see page 19 for figures
n/a	LACMHC-12735	6.55	26.70	24.5318	27.3137	L	femur head not fused
n/a	LACMHC-12736	6.00	23.45	25.5863		L	Distal ephysis: 1.6 (pic 8)
n/a	LACMHC-12737	5.90	22.50	26.2222	25.3674	L	
n/a	LACMHC-12738	5.60	20.15	27.7915	22.7179	L	
n/a	LACMHC-12739	4.60	18.15	25.3443	20.4630	L	
n/a	LACMHC-12740	4.15	15.10	27.4834	17.0243	L	
n/a	LACMHC-12742	6.35	26.15	24.2829		R	
n/a	LACMHC-12743	6.60	26.25	25.1428		R	
n/a	LACMHC-12744	6.10	24.95	24.4488		R	
n/a	LACMHC-12745	6.90	25.55	27.0058		R	
n/a	LACMHC-12746	6.45	25.45	25.3438		R	
n/a	LACMHC-12747	6.95	25.90	26.8339		R	
n/a	LACMHC-12748	6.20	24.20	25.6198		R	
n/a	LACMHC-12749	5.90	23.55	25.0530		R	
n/a	LACMHC-12750	5.40	22.60	23.8938		R	

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Table 23 (continued)

n/a	LACMHC-12751	6.40	24.20	26.4462	25.9720	R	proximal end not fused
n/a	LACMHC-12752	5.80	23.40	24.7863	25.1135	R	proximal end not fused
n/a	LACMHC-12753	5.90	22.55	26.1640	25.4238	R	both ends not fused
n/a	LACMHC-12754	5.70	20.10	28.3582	21.5718	R	proximal end not fused
n/a	LACMHC-12755	5.05	18.55	27.2237	20.9140	R	both ends not fused
n/a	LACMHC-12756	4.50	15.25	29.5081	17.1935	R	both ends not fused